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AN ANALYSIS OF THE REQUIREMENTS FOR, AND THE BENEFITS AND COSTS--ETC(U)
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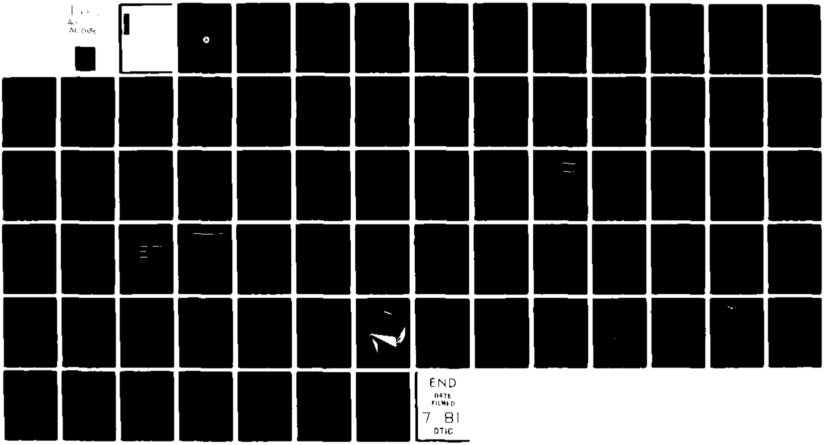

(14)

REPORT NO. FAA-EM-80-7

EXECUTIVE SUMMARY

AN ANALYSIS OF THE REQUIREMENTS FOR, AND THE BENEFITS AND COSTS OF THE NATIONAL MICROWAVE LANDING SYSTEM (MLS)

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(11) June 1980

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Springfield, Virginia 22151

Prepared by
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Office of Systems Engineering Management
Washington, D.C. 20591

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-EM-80-7	AD-A100 136	

4. Title and Subtitle	5. Report Date / 6. Performing Organization Code / 8. Performing Organization Report No.
An Analysis of the Requirements for, and the Benefits and costs of the National Microwave Landing System; Executive Summary	5. Report Date: June 1980 6. Performing Organization Code: AEM 8. Performing Organization Report No.
7. Author(s) William C. Reddick Eugene S. Rehrig Seymour M. Horowitz Gilbert P. Christiana	
9. Performing Organization Name and Address Department of Transportation Federal Aviation Administration Office of Systems Engineering Management Washington, D.C. 20591	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington, D.C. 20591	13. Type of Report and Period Covered 14. Sponsoring Agency Code

15. Supplementary Notes

Study performed and completed in 1976.

16. Abstract

This report consists of three volumes, i.e.: (1) this Executive Summary (2) Volume I comprising the detailed study analysis, and (3) Volume II which contains reprints of important studies supporting the analysis included in the report.

The analysis assesses the comparative desirability of implementing the MLS equipment option in place of the currently installed ILS as the long term National standard for precision guidance service. An evaluation period of 20 years, to the year 2000, was used for this assessment.

An implementation strategy was devised to achieve the estimated National requirement for 1250 ground installations by the year 2000 and providing precision guidance service, alternatively, with the ILS or MLS equipment option.

The study's method was to examine the technical and performance specifications for the MLS and to estimate the dollar amounts of benefits resulting from the portion of these specifications which could be quantified. The dollar amounts of comparative costs to the community of aviation users and to the FAA from the alternative use of MLS instead of ILS were, likewise, estimated.

The study results show that implementation of MLS can provide sizeable benefits in excess of costs, in varying degrees, to the different aviation user groups (i.e., air carriers, commuter airlines, general aviation and the military).

17. Key Words	18. Distribution Statement
Microwave Landing System (MLS) Cost/Benefits Analysis	Document is available to the public through the National Technical Information Service, Springfield Virginia 22151

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

PREFACE

This report, "An Analysis of the Requirements for and the Benefits and Costs of the National Microwave Landing System (MLS)," is composed of three volumes: 1) an Executive Summary; 2) Volume I, requirements and analysis; and 3) Volume II, consisting of supplemental and appending reports to support the analysis.

The purpose of this report is to acquaint the aviation user with the arguments favoring the choice of the MLS as a long term national standard for precision guidance service. The arguments presented are analytical and attempt to quantify the dollar benefits and costs resulting from the use of MLS equipment in place of the presently installed Instrument Landing System (ILS). Separate dollar amounts of benefits and costs have been estimated by individual category of aviation user (airline; general aviation), airport type (major hub; small community), and class of service provided (CAT levels I, II or III).

The study was conducted in 1976. All dollar figures are estimated in the constant-value purchasing power of the 1976 dollar. These dollar amounts have, quite naturally, been influenced by recent events and by the effects of inflation, but none of these influences have served to change any of the fundamental issues discussed in this report or to alter its recommendations. The reader may choose to use an appropriate price index to update the dollar estimates shown to some more recent date, but the ratios of dollar benefits to costs which are used by the study to support its recommendations will not be affected by this procedure for adjusting for inflation.

Due to inflation, the costs of MLS ground and avionics equipment have risen since 1976. In addition, the calculation of dollar benefits, in particular those benefits resulting from the avoidance of aircraft delays and based on current operational costs, have also risen. Since the costs for aviation fuel have increased aircraft operating costs at a faster rate than the national trend for electronics equipment, the dollar estimates shown are more likely to understate MLS benefits rather than avionics costs. A favorable verdict for the MLS rendered in 1976 dollars will, therefore, only be reinforced by any attempt to update these dollars to the present date.

There is an additional hazard due to the possible misinterpretation of the dollar estimates shown that is independent of how recent these estimates are. For example, the system costs shown in this report represent the total of dollar expenditures envisioned for the entire ("life-cycle") planning period of 20 years for the two alternative programs -- ILS or MLS -- being considered. However, these system cost calculations depend on the specific implementation strategy and the other analytical assumptions employed by the study. For this reason, while the <u>unit</u> costs of avionics and ground equipment shown in this report represent the best consensus of industry and governmental estimates as of May 1976, and may be cited in this context, the reader is advised not to quote the dollar amounts of <u>total</u> system costs outside of the analytical context in which they were generated.

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THE STUDY OF THE BENEFITS AND COSTS OF A NATIONAL MLS PROGRAM

Introduction and Precis.

- The limits of the benefit/cost mechanism for making investment decisions.
- A description of the study's methodology and analytical assumptions.
- Performance benefits quantified in dollars; not quantified.
- Study results.

A study has been conducted of the benefits and costs associated with implementing the Microwave Landing System (MLS) to complement and eventually replace the existing Instrument Landing System (ILS). The attached Executive Summary of "An Analysis of the Requirements for, and the Benefits and Costs of the National Microwave Landing System" dated December 1976, fulfills the requirements of "Part II - Assessment of Precision Transition Plan" dated January 10, 1979. Although this study was conducted in 1976, the fundamental results are still valid. The study concludes, based upon a comparison of the differences between the two systems that could be quantified objectively and in dollar amounts, that the MLS is a superior long-term economic alternative to ILS.

Studies of benefits and costs, although essential to a program's assessment, cannot be the sole basis for making an investment decision. These benefit-cost studies are limited to those factors that can be measured, even though other factors which are not quantifiable may be more important. All measurements used in benefit-cost studies must be based on fundamental assumptions concerning the future world. The assumptions can never be proven in the present world and are always subject to challenge.

The study, therefore, states its assumptions, describes what it has measured based on these assumptions, and is explicit in identifying the significant factors that have been excluded from its dollar calculations.

A benefit-cost study can be a valuable tool for judging the program's investment opportunities if the assumptions and measurements made in its own analytical world represent a realistic or a "worse case" assessment in comparison to the probable and future real world.

In the following sections, a brief description will be provided of the study's conclusions: its major assumptions, what it measured, what it did not measure, and the likely impact on the decision to invest resulting from the omission of factors which are identified, but not measured.

I. Basic Study Methodology - The Analytical World Assumed.

a. The study used a 20-year planning horizon to examine the ability of two approaches -- ILS and MLS -- to satisfy the nation's stated requirements for precision approach and landing guidance service. This does not mean that ILS service is assumed to cease operations and the providing of benefits after the 20-year period. A period of some finite length must be assumed for the analysis in order to compare alternative investments. The shorter the period, the less favorable is the investment opportunity provided by any new program since setup and installation costs must be spread over a period of appreciable length before it can compete economically with the equipment already in place.

A 20-year planning horizon -- from 1980 to 2000 -- is considered a reasonable period for comparing major new investment programs for the following reasons: (1) forecasts of flight activity are uncertain beyond the year 2000 (no official FAA forecasts exist) and (2) the effect of a discount rate of 10 applied to all future dollars is to dimish their impact to approximately 15 percent of the nominal values incurred in the year 2000. If one were to assume a 40-year planning horizon, by the year 2020 the effect of discounting would diminish the dollar values incurred in that year to a mere 2 percent of their nominal value.

It is important that the assumed choice of a planning period not favor the program being proposed. A 20 year horizon of analysis, which is a typical period for evaluating the FAA's electronic and technical equipment investments, meets this standard. The MLS program, which is estimated to be capable of providing a favorable rate of return on investment within 20 years, would yield an even more favorable economic verdict if benefits and costs were estimated [illegible] longer program horizon.

b. The study assumed that the costs to maintain the ILS ground systems plus costs to allow for the forecasted growth in ILS airborne avionics would be included as MLS costs for the first 10 years of the 20-year planning horizon. The period during which the costs for operating the ILS are to be charged to the new MLS system is referred to in this report as a "transition period." Perhaps a better choice would be to call this a period of "ILS cost burden to the MLS," although such a choice is hardly more descriptive. The assumption of a transition period of some finite length was also necessary for estimating the dollar benefits for the MLS. Benefits were estimated as beginning to accrue at a point halfway through the transition period and to build from a rate of 50 percent of annual dollar benefits to its full effectiveness by the end of the transition period. Thus, the transition period is an analytical device employed by the study for the purpose of estimating and apportioning MLS dollar benefits and costs during the period following its introduction. A nominal period of 10 years was assumed by the study; evaluations were also conducted for periods of 5 and 15 years. The study made no assumptions concerning the

actual operational life of the ILS. The final date of full transition (in the operational and not cost accounting meaning of the word) to MLS and the shutdown of the ILS can take place after as long a period as necessary to ensure maximum service with minimum disruptions, and still be compatible with the analysis presented in this report.

c. A realistic plan for implementing the MLS is the subject of an independent planning evaluation by the FAA. This plan, the MLS Transition Plan, will be published separately and will conform more closely to the real world alternatives available to MLS equipment at specific locations.

The actual number of runway locations qualifying for the new precision guidance equipment, as well as the sequence in which qualified locations will be implemented, depends on established installation criteria. The current standards established for the ILS are contained in Report No. ASP-75-1, which is appended to this study (Volume II). The categories of benefits and cost, and the method prescribed for their measurement included in the ILS-Criteria report, ASP-75-1, are consistent with the dollar amounts estimated in this study.

The best sequence for implementing the MLS -- the sequence or plan which maximizes the national benefit -- is one which implements this equipment in a descending order of need at specific locations. "Need" is defined and measured by the excess of dollar benefits over costs at these locations. There is a large measure of circularity here. In order to estimate the total of net benefits accruing to the nation -- the purpose of this study -- it is first necessary to know these benefits at specific locations so that the best implementation plan can be devised to enable national benefits to be calculated. A typical method for breaking the circle is for the comparative analysis of investment alternatives to select some nominal, plausible, and easily understood schedule for implementing the new equipment. By definition, this schedule will produce fewer national benefits than the theoretically optimum one which requires that benefit/cost ratios be calculated at individual locations and implemented in a descending order of magnitude. The implementation schedule used in this study's analysis is thus a "worse case" strategy. A proposed MLS program which shows to economic advantage as a result of employing this strategy would yield an even greater advantage by making real world implementation decisions that are wiser and more thoughtful than those assumed in the study.

The study assumed a linear build-up of MLS to fully stated national requirement levels. This MLS implementation strategy is designed to reach equivalence with the ILS in the number of installations that would be in place by the year 1990. Both systems are then estimated to achieve the same full system requirement levels, at an identical schedule of implementation, by the year 2000 (see figures 4 and 5). The costs to the FAA to operate the full network of ILS ground systems that would be in place by the year 1980 are charged in the study as redundant costs or an "ILS burden" to the MLS system. This ILS burden to the MLS cost estimates is assumed to continue until a period which is halfway through the 20-year planning horizon, the year 1990. However, by making the earlier MLS installations at airport runways not currently served by ILS and in some cases unable to be served by ILS, these redundant ILS costs could be avoided as actual costs to the FAA.

For the aviation user, the study assumed that the following categories of ILS avionics costs are, likewise, to be charged as an ILS burden to the costs estimated for the MLS for a period of 10 years after a decision to implement the MLS is made:

(1) an investment in new ILS avionics to replace those ILS units that will be older than the assumed useful life for this equipment (15 years); replacement to be made with both ILS and MLS avionics;

(2) the purchase of complete sets of both ILS and MLS avionics for future aircraft entering the fleet; and

(3) the total of operating costs needed to maintain the entire fleet of ILS avionics during the transition period to MLS ending in 1990.

For analysis purposes, these sums are added to the MLS cost estimates but need not be actually spent to the full MLS allotments shown. Once a decision to implement the MLS is made, aircraft owners may choose to postpone their replacement of ILS equipment that is 15 years old with both ILS and MLS avionics. In the same way, the owners of aircraft newly entering the fleet and equipped to receive precision guidance service may choose to transition to MLS earlier in order to avoid the dual costs for ILS and MLS avionics. For this reason, the actual costs to implement MLS avionics may be considerably less than those estimated by the study.

In summary, the study's assumption of: 1) a relatively short 20-year planning horizon, 2) the build-up of MLS to achieve equivalence to the ILS in the number of ground and airborne installations within the first half of the planning period, and 3) the use of a method for assessing those ILS costs that realistically could be avoided but analytically are charged to the MLS, all lead to the conclusion that the description of the MLS investment opportunity resulting from the use of the study's methodology will be understated. Moreover, the use of a government-wide prescription to discount all future benefits and costs resulting from a proposed program at a rate of 0.10 (prescribed by the Office of Management and Budget Circular A-94) serves to reinforce this conclusion: the costs of early and rapid implementation to MLS are measured in "high value" (low discount) dollars, while the full benefits from MLS were not assumed to accrue until the end of the transition period, and are measured in "low value" (high discount) dollars.

II. The Factors That Could Be Quantified.

The study was able to quantify the additional benefits in selected categories that would accrue to the MLS program by the year 2000, if this program were implemented as the National Standard of precision approach and landing guidance service in place of the ILS. Additional benefits from MLS service were quantified in the following categories: (1) improved safety, (2) alleviation of flight disruptions due to weather-reduced minima, (3) increased reliability of ground equipment (reduced vulnerability to weather effects), (4) increased operational flexibility due to the ability to make curved approaches resulting in the opportunity to eliminate conflicting airspace routings at selected major hub area airports, and (5) the elimination of ground signal reflections at selected airports.

On the cost side, the implementation of MLS affords the following opportunities: (1) reducing excessive site preparation costs, (2) avoiding the costs to convert both airborne and ground ILS equipment to narrower frequency separation, and (3) obtaining the lower operating and maintenance costs available from MLS ground equipment.

Benefits and costs were identified separately for the individual categories of aviation users and for the FAA.

III. The National Requirement Level For Precision Guidance Service.

The best estimate of the Nation's requirement for precision guidance service -- using current ILS installation criteria, official FAA forecasts of flight activity, and assuming that the present distribution of patterns of air carrier service to the small community airport will continue for the next 20 years -- is for a network of 1250 Federally operated ground systems in service by the year 2000. In 1976, there were about 600 ILS units installed at airports in the U.S. By 1980 the estimated total is for some 728 units. The economic analysis conducted by the study and shown in this report is based on a National requirement for precision guidance service that will provide for a network of 1250 ground systems by the year 2000.

IV. Sensitivity of Study Results to the Number of Ground Systems Installed.

It is necessary for a quantitative study of alternative investment opportunities not only to estimate the dollar amounts of benefits and costs for a proposed program operating under its most likely (average or expected forecast) conditions, but to estimate the changes in study recommendations that would occur if the conditions forecast by the study were to change. Forecasting is a treacherous business, and a study's results may be extremely sensitive to small changes in the these forecasts. This is, indeed, the case for this present evaluation of alternative equipment types capable of providing precision guidance service. For this reason it is essential to consider how the study's recommendations would change under the separate and alternative condition that the forecast of the National requirement for this service was: a) overestimated, or b) underestimated by the study.

a. The Likelihood and Consequences of Using an Overly Optimistic Forecast of Requirements.

The lower the National requirement for precision guidance service -- the larger the gap between an optimistic forecast and the actual requirement -- the more economically favorable is the choice of the ILS system. At presently installed levels, neither the additional benefits estimated by the study's methodology for the MLS nor the future savings in the FAA's operating and maintenance costs are sufficient in their total amounts to offset the investments costs necessary to implement the new MLS system. The MLS's ability to avoid the high costs for ILS site preparation, for example, is not an economic

advantage when these costs have already been sunk in the incumbent system. As the requirement for precision guidance service grows and new installations are needed, the economic advantage moves toward the MLS. The study estimates that this advantage is not sufficient to alter the verdict favoring the ILS until the requirement level reaches the 930th installation.

The change in economic verdict at this level is due to the study's determination that there will be a severe limitation in the number of available frequencies or channels of communication for ILS ground installations in excess of 930 units. No such limitation exists for the MLS system. To prevent the ILS equipment from delivering restricted service at those congested hub areas where the communication frequency problem is likely to be most severe, it would be necessary to modify the ILS system to provide more frequencies. A large segment of the airline user population has already had its ILS avionics equipment retrofitted to accept 50 kHz channel separation in place of the currently available 100 kHz separation. The costs necessary to retrofit the equipment of the remaining segments of the aviation user community in order to obtain additional communication frequencies have been estimated for each aviation user group and charged to the ILS investment cost account (tables 1.3-7 thru 1.3-12; Vol. I). The 930th installation is forecast to be made in 1988. The study estimated that the retrofit costs could be postponed to this date. Due to the effects of discounting, this results in a lower cost impact to the ILS. Nevertheless, the economic verdict shifts in favor of the MLS in this year (table 1.3-19; Vol. I).

In order for the National requirement for precision guidance service to remain below 930 installations, aviation flight activity would need to be curtailed to one-fourth of the growth level shown in the official FAA forecasts. However, a three-fourth decimation in the rate of growth forecast for flight activity would be economically detrimental not only for the MLS program but for the economic well-being of the entire aviation community as well. There would be little need for any engineering/developmental programs or long-range FAA planning activity.

The prospect is remote for a decrease in aviation flight activity of such severity as to hold the National requirement for precision guidance service below 930 installations. The consequence of such a drastic decrease in activity will have a significant effect on any decision to implement the MLS. A costly investment in new equipment could be avoided.

b. The Likelihood and Consequences of Using an Overly Pessimistic Forecast of Requirements.

Any National requirement that exceeds the forecast level of 1250 ground systems would favor the choice of MLS equipment. Before discussing the likelihood of this occurring, it is essential to note that the consequence of underestimating requirements is heightened dramatically at the 1400 ground installation level. This change is, again, due to the problem of channel congestion that results in a shortage of assignable frequencies. Despite the fact that corrective action, a retrofit of equipment, was estimated to have been completed at the 930th installation level, the continued installation of ILS equipment would be accompanied by a worsening of the channel congestion problem to such an extent that future

installations would be limited to a maximum level of approximately 1400 units. ILS installations made in excess of this limit will not provide full unrestricted CAT I, II or III levels of service, particularly in busy hub areas. The ILS cannot satisfy a requirement for precise guidance service in excess of 1400 ground systems; the MLS is the remaining alternative. It is, thus, pertinent to examine now the possibility that the requirement level will reach or exceed the 1400 system level:

(1) Subsequent to the completion of the study, the "Airline Deregulation Act of 1978" published its intention to provide the same level of safety to airports served by commuter airlines as those provided by air carriers. In addition, this Act serves to encourage air service through secondary and satellite airports, using subsidies, if appropriate, to maintain continuous scheduled air service to small communities and isolated areas. A recent study conducted by the FAA Office of Aviation Policy indicates that there are 307 airport communities served exclusively by commuter airlines, with a growth potential to 431 airports. Most of these airports do not provide precision guidance service, and many would now qualify for this service under existing criteria.

(2) A trend to the increased use of jet aircraft to serve the small community airports will result in more of these airports qualifying for precision guidance service. Passenger jet aircraft used in commercial aviation qualify those airports from which they operate for precision guidance service under existing ILS Establishment Criteria, regardless of their flight activity.

(3) The recently announced FAA "satellite reliever-airport" program, combined with the Deregulation Act of 1978, will result in the increased use of small community airports receiving air carrier service. The FAA has stated its policy that service at these small airports will be held to the same safety standards as those imposed on major airports. This policy will result in more precision guidance equipment being installed at small airports, and may require a revision in Establishment Criteria in order to qualify this equipment. Any revision in criteria that results in the need for more precision guidance service will favor the installation of MLS, and will probably be sufficient to make MLS the single available alternative to provide this service.

(4) Finally, the forecast of the average annual rate of growth in aviation activity used in the study is for a rate of 4.8 percent. A small error in this forecast, or some other reason (for example, the effects of the Deregulation Act) that results in a 10 percent increase in the rate forecast -- a change in the annual rate of growth from 4.8 percent to 5.3 percent -- is estimated to lead to an additional 150 runway ends being qualified for precision guidance service. The total of systems required would now be forecast as 1400.

The summary conclusion is that while there are significant consequences affecting the choice of equipment types that result from a forecast of the National requirement for precision guidance service being off its mark, the consequences are not the same in both directions. The consequence of following the study's recommendation to implement the MLS as the superior, long-term, National standard for precision guidance equipment, in the face of an actual reduction in the need for this equipment, will be the purchase of more

costly equipment with accompanying benefits that do not fully justify the increase in costs. However, there is no compromise in the quality of service provided; the quality of service is likely to be enhanced. On the other hand, the consequence of an error in choosing the ILS alternative with limited growth potential when the actual requirement for this equipment exceeds this limit, is much more severe. There will be a restriction in service, at the most active runways located within densely travelled hub areas, to operational minima which are below the nominal levels established for CAT I, CAT II, or CAT III levels of service. The result will be a compromise in safety, and/or an increase in diversions and delays. Moreover, the description of the future events that lead to an excess of actual over forecast requirements -- to such an extent that MLS will be the clearly preferred alternative -- indicates that these events are much more likely to occur than those which result in a reduction in a requirement level that is favorable to the ILS. The consideration of both the likelihood and consequence of making the wrong decision favors the recommendation to implement MLS. The following study results which are based on the forecast requirement for a network of 1250 ground systems are, therefore, not only confirmed but are reinforced by an analysis of the sensitivity of results to the National requirement level established for precision guidance service.

V. Study Results. The Economic Comparison of the ILS and MLS Alternatives Evaluated at a National Requirement Level of 1250 Ground Installations. The Dollar Estimates of Benefits and Costs.

Based upon those economic factors that could be quantified (see section II, above), the benefits to the aviation user community provided by MLS service (shown in table 2, p.18, arranged by user group) are some $671 million (1976 constant-value dollars) greater than the benefits that would be provided by ILS service. These incremental (MLS minus ILS) dollar benefits occurring in a given year during the 20-year planning horizon considered by the study were discounted at a compound rate of 0.10 per year, and then aggregated to a present value total of $671 million. These additional dollar benefits are more than sufficient to offset the incremental (MLS minus ILS) costs necessary to provide MLS service.

The additional costs in avionics, aggregated over a 20-year planning period and discounted at a rate of 0.10, that are necessary to implement the MLS system are $173 million (shown in table 5; p.28, arranged by aviation user group). The excess of incremental benefits over costs is, thus, ($671 - $173 or) $498 million, a ratio of 3.9 to 1. This provides a sufficient reason for concluding that, on the basis of those factors that could be quantified, a decision to implement the MLS can be justified economically.

Not all aviation user groups were determined to benefit equally from the implementation of MLS, however. The operators of commercial airlines were estimated to have a significant economic advantage, represented by a benefits to cost ratio of 8.5 to 1 (shown in table 10, p.38). Even if the dollar estimates for savings in passenger delay times were excluded as dollar benefits actually accruing to the commercial airlines, the remaining $300 million in incremental benefits, compared to the additional costs for avionics of $69 million, yield a favorable ratio of 4.3 to 1.

Similar estimates were compiled for the commuter airlines and indicated that additional benefits of $22 million could be obtained with an additional cost investment in avionics equipment of $9 million; a favorable ratio of 2.4 to 1.

An economic disadvantage -- costs exceed benefits -- was estimated for the comprehensive category of general aviation users, although some segments of this category do show substantial benefits in excess of costs resulting from the use of MLS. From table 10, p.38, it can be seen that of the total of $230 million in investment costs required to purchase MLS avionics, $63 million (27 percent) of this amount was required to replace 15-year-old ILS avionics equipment with new ILS and MLS equipment during a 10-year period following the implementation of the MLS program, or to equip new aircraft entering that fleet during this 10-year period with redundant ILS and MLS avionics equipment. For many first-time general aviation users of precision guidance equipment, these ILS burden costs that are charged to the MLS account could be avoided. Their initial installation could be postponed and made with MLS equipment only installed at an economic advantage. In addition, the benefits from increased safety -- resulting from receiving precision guidance service at those locations not able to receive full, unrestricted service with ILS, and correctable to full service with MLS -- will become newly available to this segment of the general aviation category.

From table 2, shown on p.18, it can be seen that the additional safety benefits resulting from the use of MLS in place of ILS are greatest at the small community airports (types C and D) that serve the general aviation user. These safety benefits are generated by the difference in the number of runway locations able to receive unrestrictive service to full category level I with MLS in place of ILS. No benefits were estimated for the MLS if the ILS were able to provide full CAT I precision guidance service. No potential benefits were estimated, for example, to result from a superior quality of MLS signal. ILS ground equipment already in place at the major or medium sized airports (types A or B) were determined to have fewer numbers of runway installations providing restrictive service. The safety benefits were estimated to be greatest at those runway ends that will be newly qualfied to receive this service (at airport types C and D) by the year 2000, up to a total National requirement of 1250 ground systems. The large majority of the new qualifiers will be at the small community airport locations serving the general aviation user. In addition, if National requirements were to exceed the forecasted total of 1250 ground systems (see discussion in paragraph Iv.b. above) the vast majority of the additional and newly qualified runway ends would, likewise, be located at the small community airport serving the general aviation user.

Still, a consideration of the total amount of additional MLS benefits and costs, estimated by the study's methodology for all airport locations, reveals an economic disadvantage to the general aviation user. The economic penalty is for quite modest dollar amounts, however, as the following paragraphs reveal.

A total of $2 million (valued in dollars of 1976 purchasing power, accumulated over 20 years and discounted at a rate of 0.10) in excess costs compared to benefits was estimated as the economic penalty for the owners of single

and multiple engine propeller aircraft. For the owners of corporate jet aircraft, the amount of the net disbenefit accumulated over 20 years was estimated as $27 million. This latter group was assessed with particularly burdensome economic assumptions compared to the owners of the other categories of general aviation aircraft. On the cost side, a heavy economic penalty was imposed by the conservative assumption that corporate jets would have 100 percent equipage with sophisticated avionics, but no allowance was made on the benefits side for the increased value of the cargo or for the higher dollar value of the time saved by the passengers carried in these aircraft.

These assumptions point up a serious limitation to the use of benefit-cost analyses for estimating the value of special or individual programs. These analyses are necessarily devoted to the consideration of averages. For example, in estimating the value of time saved by a passenger in air travel, the analyst is aware of the fact that many significant variables contribute to this estimate and include: 1) the purpose of the trip (an emergency, business trip, pleasure, etc.), 2) the passenger's income (if the passenger is paying for the trip), 3) alternative modes of travel (which, in turn, depend on the distance of the trip and other factors), 4) a host of social, economic and psychological variables (age, health, anxiety level, etc.). The dollar value to be placed on time may even be thought of as forcing the analyst to enter the realm of metaphysics where measurement is, indeed, difficult. Yet, quantitative studies seem to indicate that the average air traveler acts as if he values his time at a dollar value equal to his income-earning capability. For this reason, benefit-cost analyses often resort to a determination of the national average income for the air traveler population, and estimate the average value of time as equal to the income earning ability of this average traveler. This study, therefore, used an average (median) salary of $25,000 per year (2000 working hours) to arrive at an estimate of ($25,000 divided by 2000 hours, or) $12.50 per hour, as the dollar value of time saved in avoiding aircraft delays or disruptions.

It is reasonably certain, however, that there are no owners of corporate jet aircraft who earn $25,000 a year, and very few owners of multi-prop or single-prop aircraft. The general aviation user is not an average traveler earning the national average income. On the basis of the analysis and assumptions used in the study, there would be no way economically to justify the purchase of a general aviation aircraft, let alone the alternative purchase of MLS avionics to be installed in its cockpit. Government studies of national programs must be concerned with average values and with national benefits or utilities, but the determination of the worth of MLS avionics in place of ILS to the general aviation user must be made on the basis of the individual owner's scale of preferences and utilities. In this instance of attempting to measure the general aviation aircraft owner's preference for avoiding aircraft delays, it is likely that the dollar amounts calculated are significantly understated.

Finally, the study concluded that there is an economic advantage to the FAA as the manager of the network of ground facilities. This advantage is not estimated by a ratio of benefits to costs but is described by the savings in total program costs required to satisfy the National requirement for precision guidance service. From table 8, p.35, it can be seen that these savings amount to $40 million, accumulated for 20 years for all airport types and Category I,

II or III levels of service, discounted at a rate of 0.10. These savings to the FAA, in providing a network of 1250 ground systems, are about evenly divided between savings in investment costs ($18 million) and savings in operating expenses ($22 million).

VI. Factors Not Quantified In The Study.

The following items are essential to the evaluation of MLS, but they are not readily measurable and were therefore excluded from the dollar calculations of benefits and costs:

a. Reduction in Noise Levels.

At many major airports, the curved approach feature available with the MLS and its potential usefulness in transferring noise profiles to less populated or noise-sensitive areas may be a valuable way to reduce noise on approach and departure patterns. Since agreement could not be reached on an analytical method for estimating how precise dollar values can be attributed to reductions in noise, no quantifiable benefit was claimed for the MLS.

b. Capability for Variable Glide Paths.

The MLS provides an ability to restructure approach paths at certain airports to permit segregated approaches to short runways by general aviation and helicopter operators. The use of the variable glide paths available with the MLS might permit small aircraft to follow "heavies" at a higher glide path angle as a means to ensure protection from wake turbulence. These and other potential changes in approach and departure procedues add to the increased operational flexibility available with MLS; a flexibility that is capable of yielding significant reductions in flight delays. These changes in procedures represent a potential benefit only. A comprehensive consideration of their technical feasibility was not included in the study, and no objective analytical method for measuring the economic impact of an unapproved but potential change in operational procedures is known at this time. However, the identification of the potential for procedural change -- the increase in the number of options available for the future and the significant reduction in delays -- represents an important economic advantage to the MLS.

c. Military and International Advantages.

There are favorable military and international advantages for MLS. While the dollar benefits from the widespread adoption of an internationally recognized standard were not included in the study's determination of benefit to cost ratios, the following dollar calculations were made:

(1) The U.S. military would benefit by a common worldwide military/civil system with an O&M cost savings of some $37 million while avoiding non-standard proliferation.

(2) A conservative worldwide market for MLS exists which has a potential value to the U.S. through export, on the order of $900 million. This does not include sales to the foreign military.

d. Enhanced Signal Quality.

The inherently higher MLS signal quality provides for the potential development of better flight control systems that can be coupled more closely to the beam and hence contributes to the possible future and extensive use of automatic approach and landing procedures. This would provide the potential for safer precision guidance service. However, present ILS installation criteria provide a method for estimating improvements in safety down to CAT I service levels only, and an analytical method for calculating the dollar value of an improvement in safety beyond this level was not available to the study. Experiential data for CAT III landings are meager, and they must be augmented with simulations or models of reality. The validation of models capable of providing consistent and objective dollar measures of improvements in safety could not be completed in a timely fashion for inclusion in this study. However, the study's inclusion of dollar benefits for safety for service beyond CAT I levels would serve only to add to the economic benefit/cost ratio that already favors MLS.

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Section I

BACKGROUND

A. OBJECTIVES

The Instrument Landing System (ILS) has done an excellent job of meeting precision landing requirements of the National Airspace System over the past 35 years. However, it has some inherent limitations that are anticipated to become more acute and costly in the near future. Recognition of these limitations by the Federal Government and the aviation community led to the Microwave Landing System (MLS) Development Program, which has produced the Time Reference Scanning Beam (TRSB) MLS. This study is an assessment of the potential merits of the MLS development program compared to the ILS. It is the study's intent to provide DOT/FAA management with the type of information necessary to assist in their decisions on whether to: (1) proceed with the completion of the third phase of TRSB development (tactical system development), and (2) implement MLS nationally as the replacement for ILS.

B. HISTORY OF ILS AND MLS

ILS was first demonstrated in 1939, placed into national service in 1941, and adopted as the worldwide standard by the International Civil Aviation Organization (ICAO) in 1949. It is still providing satisfactory precision landing guidance at most airline airports. While only about 10 percent of the nation's airports that have paved and lighted runways also have an ILS, these ILS airports are the most heavily used in the nation. Of those airports having approved instrument approaches, only 25 percent have ILS. Yet, these airports account for over 80 percent of all instrument approaches, over 90 percent of all airline activity, and nearly 100 percent of all jet airline traffic.

Currently, approximately 600 ILS facilities are installed at airports within the U.S., and planned installations through FY 1980 will raise this total to about 728 facilities. However, of the airports with an ILS, approximately 26 percent do not meet Category I requirements because of signal-in-space and/or obstruction constraints, or no approach lighting.

ILS functions well where installed because its limitations are known, and operational constraints are imposed based on these limitations. The FAA has taken great care that only quality installations and safe operational practices are employed. Very few accidents have occurred when full ILS was available. The limitations to ILS which have resulted in the development of a replacement system are principally those that have delayed or prevented its installation and operation at airports with siting or obstruction problems. These limitations of ILS, together with the anticipated solutions that would be provided by MLS, are shown in Figure 1.

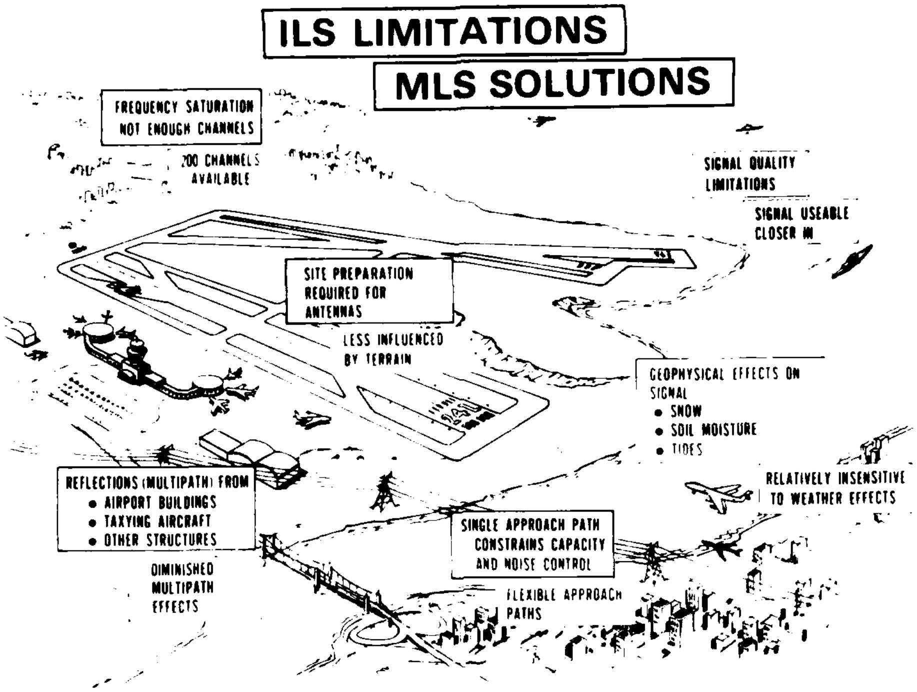

Figure 1. Major Limitations of Today's ILS, and MLS Solutions

The need for a new precision approach and landing system was documented in the Department of Transportation's Air Traffic Control Advisory Committee (ATCAC) report of December 1969[1] and by the Radio Technical Commission for Aeronautics (RTCA) in its SC-117 report of December 1970.[2] The ATCAC report indicated that the projected demand for air traffic control services would outstrip the capabilities of the present system and concluded that a Microwave Landing System was required as part of the future National Airspace System approved by FAA and DOT. The ATCAC Report added impetus and importance to the work of RTCA SC-117 which after 3 years of study, produced a comprehensive recommendation for "A New Guidance System for Approach and Landing." The MLS program was conceived as the mechanism for developing and implementing this new system, which was intended to meet both civil and military requirements through

1 "Report of the Department of Transportation Air Traffic Control Advisory Committee," December 1969.

2 "A New Guidance System for Approach and Landing," prepared by the Special Committee 117 (SC-117) of the Radio Technical Commission for Aeronautics, December 1970.

at least the year 2000. This program as described in the National Plan for Development of MLS,[3] jointly prepared by the program participants (DOT, NASA, DOD), established a three-phase development program.

The MLS program is currently in its third phase, with two Basic and two Small-Community ground system prototypes of the TRSB MLS installed at the present time for tests and evaluation. (Development of the military tactical system is awaiting approval.) A number of matching avionics systems are being delivered to permit a comprehensive FAA, DOD and NASA Service Test and Demonstration (ST&D) program prior to full scale implementation.

The dollar estimates of benefits resulting from the capabilities of MLS are summarized in Section III, Economic Analysis, of the Executive Summary. A detailed discussion of MLS requirements and benefits is included in chapter 2.0 of Volume I. A synopsis of the MLS's technical performance characteristics which created these benefits is provided below:

- Channel Congestion - MLS provides a sufficient number of frequency channels (200) to preclude the limitations being experienced by ILS.
- Signal Quality - MLS provides cleaner guidance signals closer in to "touch down" than are available from ILS. This permits certain operating restrictions to be removed that are now being applied in some locations as a result of ILS signal deficiencies; bends, roughness, and poor guidance quality.
- Difficult Sites - MLS is much less sensitive than ILS to multipath effects from terrain and airport structures. A significant benefit of MLS will be the reduction in the number of unequipped runways due to environmental effects.
- Geophysical Effects - MLS is essentially independent of the surface conditions and can, therefore, reduce the number of flights which are delayed or diverted due to landing system outages caused by geophysical effects (snow, tides, soil, moisture) on the glide slope reflection plane.
- Approach Obstructions - MLS would permit the potential use of selected glide slopes or precision curved approaches and, thereby, remove a number of site-specific restrictions.
- Offset Localizer - The MLS split-azimuth configuration can maintain its precision, thus, minimizing special restrictions that must be applied to offset ILS installations.

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3 "National Plan for Development of the Microwave Landing System," Department of Transportation/Federal Aviation Administration, National Aeronautics and Space Administration, and Department of Defense, July 1971.

- Reduced Maintenance - Both ground and airborne MLS avionics will incorporate digital solid-state improvements, which would reduce maintenance costs and the incidence of flight disruptions arising from guidance equipment outages.

- Standardization - Without MLS as the National standard, there would, undoubtedly, be a proliferation of incompatible, substandard, microwave ground and avionics systems unable to provide adequate assurance of safe performance.

Section II

STUDY APPROACH

Figure 2 depicts the approach used in this study. An important feature of this approach is the Analysis of Requirements for a new precision-guidance system (block 2 of Figure 2). The requirements were generated by an assessment of the performance characteristics available from a future MLS system. This assessment led to the identification of the beneficiaries within the aviation community and the categories of benefits provided by the MLS. The portion of these benefits which could be quantified in dollar amounts was included in the study's Economic Analysis.

A description of the physical characteristics of the MLS system that would be capable of generating benefits to the community of aviation users is provided in section IV of this Executive Summary.

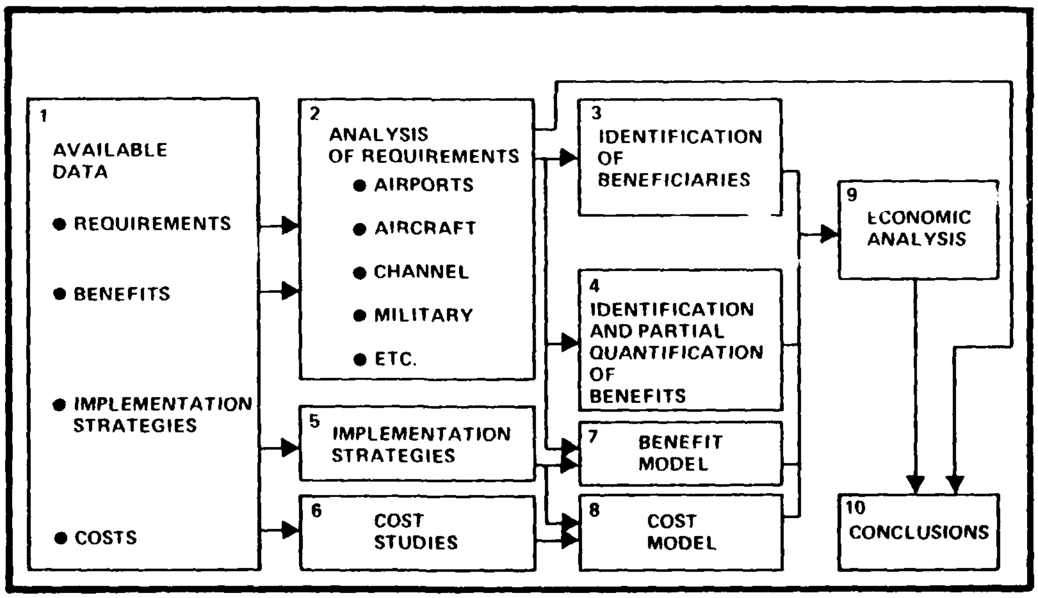


Figure 2. Functional Flow Diagram for MLS Benefits and Costs Study

The calculations of dollar benefits and costs based on these physical characteristics are shown in the Economic Analysis, section III of this Executive Summary.

The Analysis of Requirements conducted by the study included the identification of alternatives to ILS for meeting the new precision-approach system needs. The results of this analysis indicated that the National Microwave Landing System was the only alternative to continuing with ILS that could fulfill the national, international and military requirements without a further proliferation of different types of incompatible precision-guidance systems. Therefore, the implementation alternatives considered in this benefit-cost study were limited to:

- A continuation of the ILS implemention program; or

- The implementation of the MLS as a replacement for the ILS.

These two alternatives were evaluated within an analytical context and an assumed implementation schedule was devised for the purpose of reaching an economic verdict between them. Although a schedule for MLS implementation was assumed for the analytical world in which the economic comparisons were made, an examination of more realistic schedules for implementing the MLS is being conducted by an FAA Transition Planning Group and will appear subsequently in a separate document. A discussion of this planning effort is included in Appendix A of Volume I.

Section III

SUMMARY OF ECONOMIC ANALYSIS

A. OBJECTIVE

The objective of the Economic Analysis was to compare the additional or incremental dollar value of benefits derived from MLS equipment in place of ILS, to the additional costs necessary to achieve these incremental benefits. An economic verdict based on those factors that could be quantified would favor the MLS if the estimated amount of incremental benefits exceed costs. To satisfy this objective, it was necessary to:

- Quantify the additional benefits from MLS.

- Determine the additional costs.

- Devise an implementation strategy that meets future National requirement levels, and provides a method for estimating the time-series flow of benefits and costs, i.e., estimates the specific years in which benefits and costs are expected to occur.

- Establish the limits of prudent investment by determining the "turning points" or future requirement levels at which the ratio of benefits to costs become favorable (or unfavorable) to the new program as conditions or important categories of analysis change. This information would be critically important in determining the relative need for MLS and establishing the actual implementation sequence that is consistent with this need. Thus, a feature of the economic analysis is the separate estimation of this ratio for the following categories of analysis: 1) level of precision guidance service (CAT I, II, or III); 2) type of airport (large, medium, or small); and 3) aviation user group (air carrier, commuter, or general aviation). The analysis was structured to provide an economic verdict, an individual ratio of benefits to costs, for the entire range of conditions represented pictorially by the classification scheme shown in figure 3.

B. BENEFITS CONSIDERED IN ECONOMIC ANALYSIS

Section IV of this Executive Summary contains a brief discussion of the special technical and performance characteristics of the MLS that were analyzed as a part of this study. The main product of this analysis was the identification of categories of MLS benefits. It should be noted that not all of these benefits were included in the economic analysis, primarily because they could not be quantified easily in dollar amounts. When quantification is not possible, a qualitative description and assessment is provided. It is important that the reader not overlook these types of benefits.

For example, the MLS is intended as an integral part of a program to upgrade and automate the Air Traffic Control System; upgraded Third Generation of Automation (UG3RD). But no analytical method exists for estimating the

ETC.

MEDIUM HUB AIRPORT

LARGE HUB AIRPORT				
AIRCRAFT USERS / BENEFIT CATEGORIES	AIR CARRIERS	COMMUTER AIRLINES	GEN. AVIATION CLASS A, B & C	FAA
SERVICE LEVELS	I II III	I II	I II	I II III
● BENEFIT CATEGORIES IMPROVED SAFETY ● ALLEVIATION OF FLIGHT DISRUPTIONS ● ETC.	$	$	$	$

Figure 3. Structure of Benefit and Cost Comparisons

independent contribution made by the MLS when interacting with the other com[illegible] nents of the UR3RD package of automation.

The ease or difficulty in assessing a category of bene[illegible] to its importance. For example, a critical feature o[illegible] signal quality; a feature which can be expected [illegible] formance. Yet, the study could find no wa[illegible] safety or in reduced delays result[illegible] the ILS equipment at a given locat[illegible] [illegible] eve[illegible] of unrestricted CAT I service [illegible] does not reflect on the value of the [illegible] the degree of unsophisticat[illegible] benefit-cost analysis.

[illegible] ategories considered in the Analysis [illegible] and indicates those categories that [illegible] artially, and which are included in the Economic

[illegible] USER GROUPS, AIRPORT TYPES, AND LEVELS OF SERVICE

[illegible] charts and tables of benefits and costs included in the Economic Analy[illegible] are classified separately according to the following definitions of user groups, airport types, and levels of service:

1. User Groups.

   o Air Carriers: domestic owners of aircraft in domestic and international service. (Passenger benefits identified separately).

TABLE 1. MAJOR MLS
BENEFIT-CATEGORIES AND THEIR INCLUSION IN THE ECONOMIC ANALYSIS

MAJOR MLS BENEFIT CATEGORIES	$BENEFITS INCLUDED IN THE ECONOMIC ANALYSIS
• Improved Safety	√
• Alleviation of Flight Disruptions (Cancellations, Delays, Diversions)	
• Reduced Government Costs	√
• Elimination of [illegible]	√
• Improve[illegible]	
[illegible]straints	√
[illegible] Operations Constraints	√
[illegible] Approach Minimums	√
[illegible]minal Route Length Reduction	√
Noise Abatement Procedures	--
• Guidance for Future Aircraft (V/STOL, RTOL)	--
• Potential International Market	--
• Military Benefits:	
- Improvements in O&M	--
- Civil/Military Interoperability	--
- Improved Tactical Performance	--

- Commuter Airlines. (Passenger benefits identified separately).
- General Aviation (including air taxi).

  (A) Single-engine propeller aircraft

  (B) Multiple-engine propeller aircraft

  (C) Corporate jet aircraft

- Federal Aviation Administration (manager of ground systems)

2. Airport Types.

A. Large Airports. A principal air carrier airport with the estimated requirement for at least one runway to be equipped to a CAT III level of service by the year 2000. A total of 40 airports meet this description. At these airports, there are presently 81 runways equipped with ILS to a nominal level of CAT I service; 21

ways are equipped with ILS to CAT II service. The study estimated that with present installation criteria, forecasts for flight activity and patterns of air carrier service, there would be a total of 250 installations, ILS or MLS, offering precision guidance service up to CAT III levels in the year 2000.

B. Medium Airports. A basic air carrier airport estimated to have a requirement for at least one runway with CAT II service by the year 2000. A total of 110 airports are in this category. At these airports there are presently 137 runways equipped with ILS to a nominal level of CAT I service; 11 runways are equipped with ILS to CAT II service. With present installation criteria, forecasts of flight activity and patterns of air carrier service, the study estimated that there would be 400 installations, either ILS or MLS, in place by the year 2000.

C. Small Airports. A small community and reliever airport with at least one runway currently commissioned with CAT I service or with a runway that will qualify by the year 2000 under present landing criteria and using the current forecasts of flight activity and patterns of air carrier service. A total of 500 airports are in this category with, at present, 276 runways currently equipped with an ILS providing CAT I service. The study estimated that by 2000 there would be 525 installations, either ILS or MLS, in this airport category.

D. Small Community Airports (future candidate; patterns change, evaluated at APS criteria). A small community and reliever airport with no present installation of an ILS, but having at least one runway which will qualify for an ILS by the year 2000 under the present establishment criteria if patterns of providing air carrier service were to change.

Present installation criteria establish the eligibility for ILS at "airports where air carrier turbojet (emphasis added) operations are conducted on a sustained basis." With new developments in technology and the increased availability of modern jet aircraft, or with an increased demand for jet-operated air carrier service to the smaller communities, airports not previously identified would now qualify for ILS or MLS service. The study estimated some 75 newly qualified installations in this category.

3. Levels of Service for Precision Guidance. The following levels of service are defined:

- CAT I. 200-ft Decision Height (DH), 2400- to 1800-ft Runway Visual Range (RVR).
- CAT II. 100-ft DH, 1200-ft RVR.
- CAT III. 0-ft DH, 700-ft RVR.

D. IMPLEMENTATION STRATEGY

For the Continuation-of-ILS-Program alternative, the estimated implementation schedule for the ILS using the current Airport Planning Standard (APS-1) to reach a National requirement level that is forecast to grow to 1250 ground systems by year 2000, is shown in figure 4. This figure depicts the growth from a present level of 600 systems to approximately 728 systems by the year 1980, and the eventual implementation of 1250 ground systems by the year 2000. The 1400-system limit identified in figure 4 is a result of a channel limitation problem that will not permit the ILS to be implemented for requirement levels that exceed this number (discussed in Section 2.3 of Volume II).

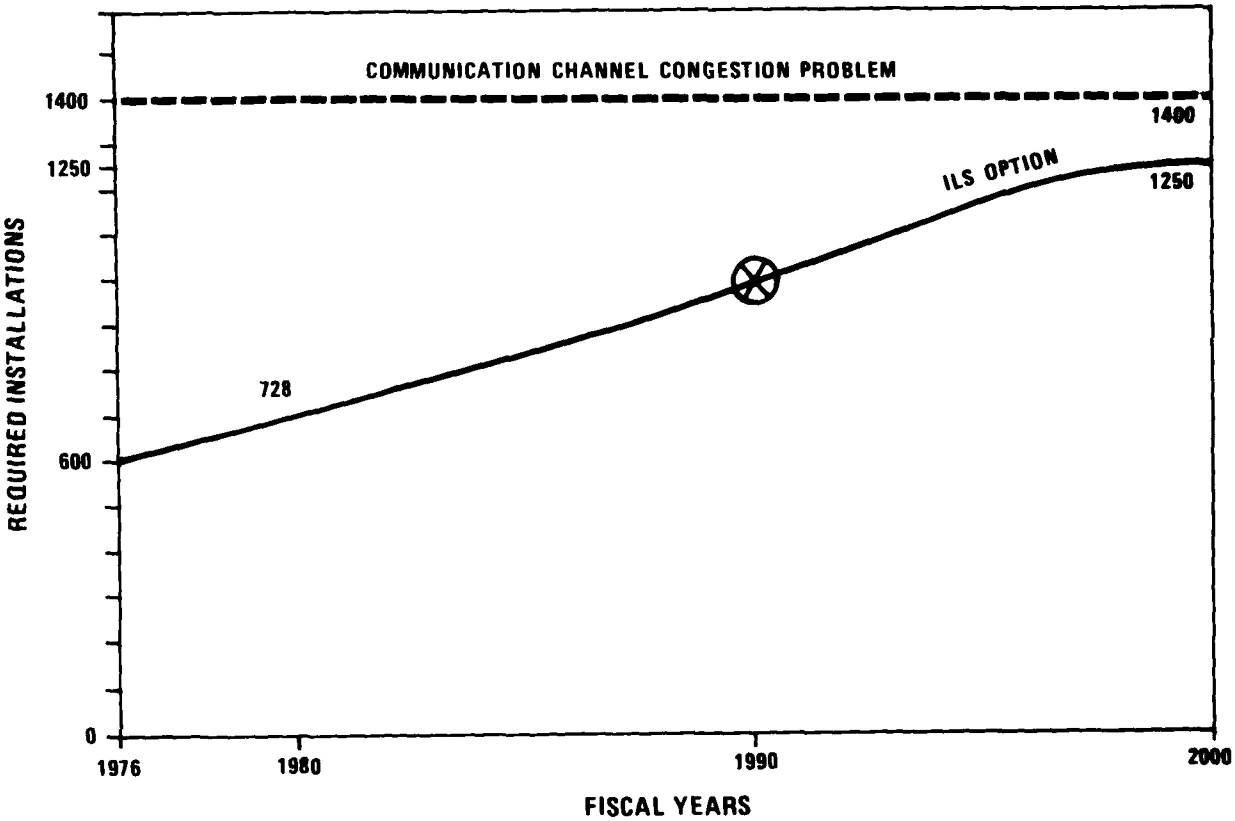


Figure 4. Option: Continue with ILS
ILS Implementation Schedule

The implementation schedule for the MLS option is shown in figure 5. The planning horizon for the MLS implementation program is assumed to be 20 years starting in FY 1980, and is divided into two time phases: (1) a transition period, and (2) a posttransition period, or normal state. During the transition period, MLS equipment (both avionics and ground systems) will be implemented at a constant, linear, rate to the full number of systems and levels of service that would be provided by the ILS Continuation-Program option at the end of the transition period. ILS installations of airborne avionics will continue

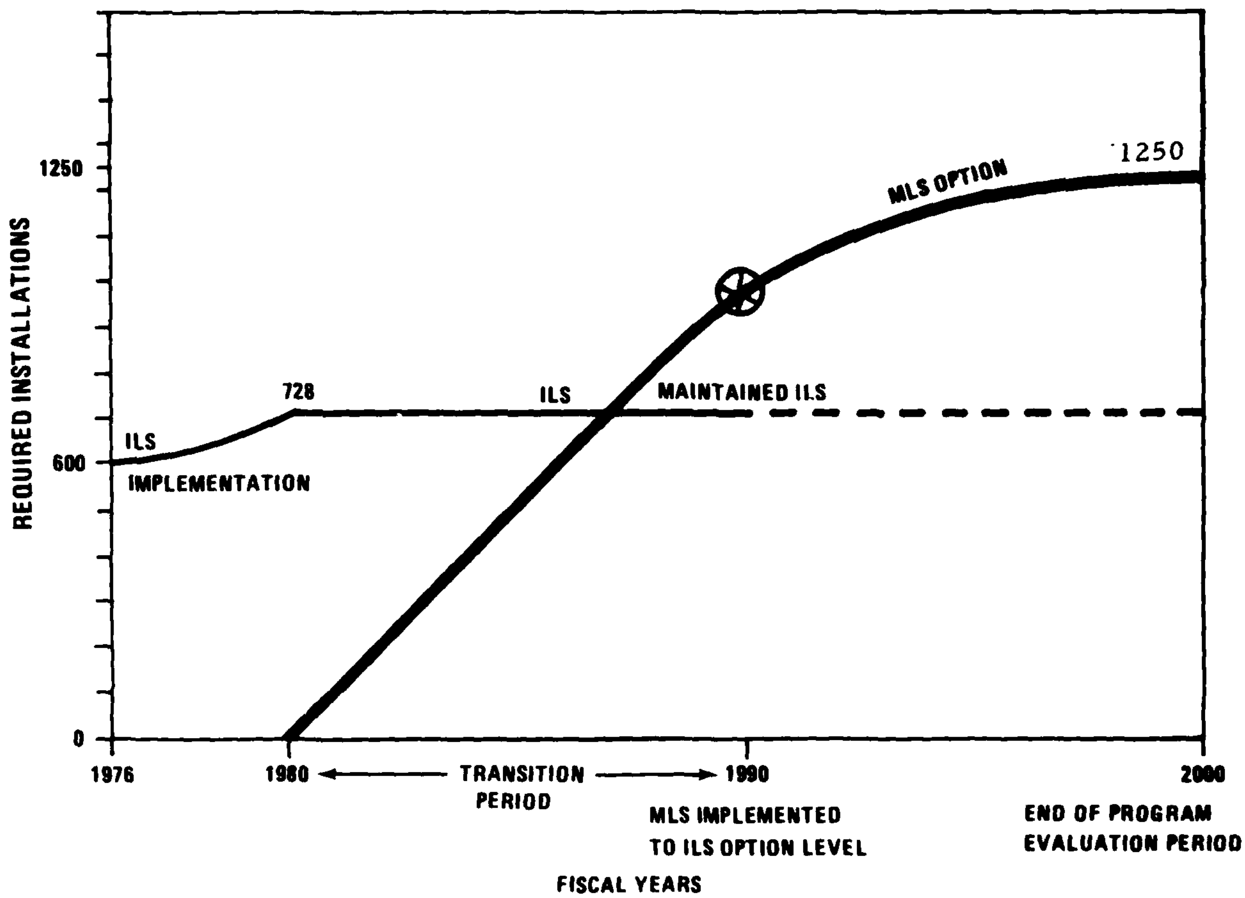


Figure 5. Option: Implement MLS
MLS/ILS Implementation Schedule.

to be made during the transition period, with the result that there will be no reduction in service offered during any year of the 20-year program to implement the MLS to National requirement levels. Full parity with the ILS would be reached by the end of the transition period. The length of the transition period was considered to be a parameter of the study. For analysis purposes, transition periods from 1 to 15 years were considered. A period of 10 years represents a realistic, nominal, example for the transition period, and the estimates of benefits and costs presented in the following paragraphs are based on this example. Calculations of estimates based on other transition-period examples are located in Chapter 1, Section 1.6 of Volume I.

During the transition period when MLS builds to ILS levels, the study made all the analytical assumptions and dollar cost adjustments necessary to assure that there would be no deterioration in service to the user of the National Airspace System (NAS). ILS avionic equipment that wears out during the transition period was estimated to be replaced with both ILS and MLS avionics. New

aircraft entering the fleet during the transition period were, likewise, estimated to be equipped with both ILS and MLS systems. The estimated costs of carrying both systems were charged to the MLS program alternative for the full length of the transition period.

For ground installations during the period when MLS builds to ILS levels, a similar assumption was made to assure that there would be no deterioration in ILS service during the transition period. To support this assumption, the same analytical procedure was used. All airport runway locations currently equipped with ILS or planned to be equipped by 1980 were estimated as continuing to provide this service. The costs to operate and maintain the ILS equipment were charged to the MLS implementation program during the transition period.

The effect of varying the length of the transition period during which time the costs to operate and maintain the ILS system are considered as part of the costs to be borne by the MLS program option, was examined in the Sensitivity Analysis conducted by the study, (Volume I, Chapter 1, Section 1.6). The shorter the transition period, the faster the rate of build-up, and the higher the proportion of costs included in the earlier, "low discount" (high present value) years. Yet, a shorter transition period also results in a lower estimate for the "burden" costs charged to the MLS for maintaining the ILS system. The reduction in "burden" costs is more than sufficient to offset the higher present value dollar costs due to the effect of discounting. The result is a net cost savings to the FAA from a shorter, five year, transition period. The study estimated, technical and operational difficulties aside, that there was also a potential economic advantage to the air carrier and commuter airline user groups resulting from the opportunity to reduce the redundant costs of maintaining two sets of avionics equipment during a shorter, five year, transition period. The general aviation user group which has less of investment already entrenched in the current ILS system and which, therefore, would benefit less from the opportunity to reduce the costs of its "ILS burden" exhibits an economic disadvantage resulting in the alternative consideration of a five year period to transition to MLS, instead of ten years.

The inclusion of a transition period is an essential feature of the economic analysis. In effect, it is the nominal implementation strategy used for installing MLS equipment. MLS equipment will be installed at a linear rate of build-up until full parity with ILS is reached by the end of the period, and the National requirement for precision guidance service as forecast by current installation criteria (1250 ground systems) is satisfied by the year 2000. There could be no calculation of benefits and costs without it.

There is only one implementation strategy that maximizes the rate of return on investment and that is to install MLS equipment at runway locations on the basis of a descending order of need, up to the maximum level set by budgetary constraints. A location's need for MLS is measured by the anticipated ratio of incremental benefits to costs resulting from a postulated installation.

Typically, the dollar benefits resulting from investments in FAA programs are directly related to some measure of activity at a given facility: for example, the more operations, the greater is the probability of (a) an accident or (b) a delay, and hence, the greater the opportunity for improvement by an FAA program. The implementation strategy that assumes that installations will be made on the basis of a descending order of activity, as a close approximation

to a facility's need for this installation, is a valid one for the vast majority of FAA programs. However, this is not the case for the MLS.

The specific and important benefit categories in which MLS can be expected to make improvements include the ability to alleviate individual installation problems such as difficult site preparations or the imposition of ILS channel limitations. These problems may be unrelated to a measure of the airport's activity, and, hence, a strategy that installs MLS equipment according to such activity does not represent the entire need for this equipment. In effect, the assumption of a uniform and linearly implemented program that includes an appropriate accounting for all benefits and costs--those related to airport activity as well as those not related to activity--enabled the study to determine a comparative estimate of the ratio of incremental ($MLS-$ILS) benefits to costs for specific airport categories and user groups. The lack of a favorable overall benefit-to-cost ratio for all users would indicate that the MLS program is not a good investment from a strictly analytical point of view. The proponents of the MLS program could argue, in this case, that the assumed implementation strategy was the cause of the unfavorable verdict. On the other hand, a favorable ratio would indicate the general advisability of investing in the program. Once a determination of the economic advisability of investing in MLS has been made, a follow-on analysis can be used to determine the strategy that would yield the best rate of return on investment. This rate could be achieved by invoking the strategy that implementation of MLS take place on the basis of a descending order of need represented by a ratio of incremental benefits to costs for individual user groups, receiving alternative levels of service, at specific airport locations. This is the strategy that is, indeed, invoked in the MLS Transition Plan, shown in the separate volumes that will accompany this analytical study. But, in order to employ a realistic schedule designed to utilize the dollar amounts of benefits and costs for specific users and airport locations, there must be a prior calculation of these dollar amounts based on some general implementation strategy assumed for analysis purposes. The strategy assumed in this study--a linear replacement of existing facilities--is simple to understand and results in a "worse case" return on investment than could be achieved by a wiser and more realistic implementation schedule.

For this reason, the evaluation of the MLS should be viewed as a two-part process: (1) A general indication of the need for MLS, shown in this volume, together with a separate indication of this need in the form of a benefit to cost ratio estimated according to user group, airport location and service level (CAT I, II or III); (2) A follow-on analysis of alternative implementation strategies for the purpose of achieving maximum economic benefit, shown separately in the volumes of the MLS Transition Plan. In this plan, the MLS installations are made according to locations of greatest need, subject to a budgetary constraint.

It is important to note that the assumption in this volume of a transition period of finite length is made for the purposes of economic analysis only. It is the period during which MLS will build to parity with ILS and during which the costs to maintain the ILS will be borne by MLS. The study is neutral with regard to when the ILS system will be phased-out operationally.

E. BENEFIT CATEGORIES QUANTIFIED

Out of the total list of benefit categories identified in table 1, the following could be quantified and are included in the economic comparison of MLS and ILS: (see Volume I, Chapters 1 and 2 for more detail).

- Improved Safety. This benefit stems from MLS equipment providing more precise guidance and improved levels of service. With MLS, more runway locations were estimated to be able to provide full, non-restricted levels of service. Locations providing less than full service are defined as "restricted." Safety benefits were estimated for CAT-I service only. Any additional safety benefits accruing to CAT-II or CAT-III landings were excluded.

- Alleviation of Flight Disruptions. Because of more runway locations delivering full, non-restricted, levels of CAT-I, -II, or -III service, there will be fewer flight disruptions due to cancellations, delays and diversions caused by weather restrictions. MLS will be capable of equipping more locations to provide full non-restricted service.

- Reduction in Arrival Delays Due to System Outages. This benefit arises from the increased operational reliability and maintainability of MLS in comparison to ILS. Increases in MLS reliability result in an improvement in the Mean-Time-Between-Failures (MTBF). These improvements, as well as reductions in the Mean-Time-To-Repair (MTR) are explicit engineering design goals that are available to MLS. In addition, it is estimated that there will be fewer outages due to environmental changes in the glide-slope ground plane (snow, soil moisture, tides). The size of the reduction in aircraft delays due to an improvement in the increased reliability of MLS precision guidance equipment was estimated from a detailed operational study at a major airport.

- Reduction in Operational Delays (Removal of Conflicting Signals in Space; on the Ground). The quantifying of this benefit is based on case studies at five airports (JFK, LGA, DCA, SEA, and SFO). The potential for an increase in Instrument Flight Rules (IFR) capacity was identified at these airports due to the curved approach capability available with MLS. This will permit delay reductions by eliminating the airspace conflicts between JFK and LGA and by decreasing the minimums at DCA. In addition, a reduction in delays was identified at JFK due to the removal of ground signal interference at an active taxiway. A similar potential for removing taxiway restrictions and improving operational capacity (both on the ground and in the air) undoubtedly exists at airports other than those examined, but these potential estimates of dollar savings are not included in the study. The delay reductions were translated into a dollar amount and fuel savings for the case-study airports only.

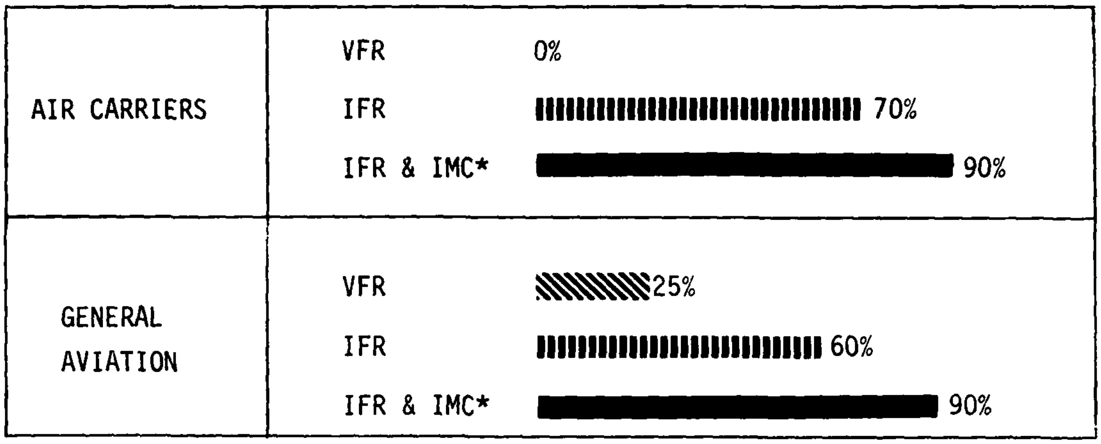
- Reduction in Path Length. It will be possible to reduce some aircraft path lengths in the approach area because of the ability of MLS to provide precision-guidance service along curved paths. This service enables a potential reduction in some approach-path lengths through more efficient ATC routing procedures. The resulting reduction in path length, which is equivalent to a reduction in flight time, was translated into a dollar savings and an associated savings in fuel.

- Elimination of ILS Channel Limitations. The investment costs to retrofit ILS equipment in order to alleviate this limitation were included in the study. In addition, this limitation to ILS performance was accounted for in the quantifying of Improved Safety and Flight Disruptions benefits for the MLS. It is a contributing factor accounting for the disparity in the number of runways that can have full, unrestricted service with MLS in place ofILS.

F. ANALYSIS OF QUANTIFIED BENEFITS

A description of the analysis and the dollar values resulting from a determination of the incremental ($MLS-$ILS) benefits accruing during a 20-year program to implement the MLS are briefly discussed in the following paragraphs for each of the identified benefit categories. To allow for sufficient MLS avionics and ground installations to be in place, benefits are estimated to begin to accrue halfway through the transition period (nominally 10 years) at 50 percent of the annual value and are estimated to grow at a linear rate of 10 percent per year, until 100 percent of the dollar benefits are assigned by the last year of the transition period.

1. Determination of Improved Safety Benefits. The basic argument used in computing this benefit derives from historical data of aircraft accidents, which show that safety is enhanced by the use of precision guidance service. The benefit from MLS is based upon the contention that there are an added number of runways that can be served to full Category-I level with MLS in comparison to ILS due to the alleviation of siting problems, channel limitations, or other signal-related restrictions. The estimates of benefits for safety were based on the methodology prescribed in the "Establishment Criteria for Category I Instrument Landing Systems" (Report No. ASP-75-1). However, the study determined that the statistic used for measuring current ILS usage at airports--Aircraft Instrument Approaches (AIA), a statistic which is recorded in IFR weather only--greatly underestimates the use of ILS. ILS service is routinely used in all weather by a large segment of equipped aircraft. For this reason, it was necessary that an estimate of ILS usage for all approach operations be acquired from technical and operational groups within the FAA. These usage rates are shown in figure 6. Based on these usage rates, an adjustment was then made to the dollar value per unit of ILS usage, shown in ASP-75-1, in order that the total value of dollar benefits claimed due to a reduction in accidents resulting from the use of precision guidance equipment was the same regardless of the measure of ILS activity used. In other words, the current dollar value of accidents prevented with full CAT-I service is the same whether measured by AIA activity or by the percentages of total operations shown in figure 6. Since AIA's are forecast to grow at a faster rate than total operations, this adjustment to reflect greater ILS activity than presently accounted for in AIA's results in a conservative estimate of future MLS safety benefits. An additional dimension of conservatism in estimating safety benefits results from the study's adherence to the guidelines suggested by the Criteria for Establishing Instrument Landing Systems contained in ASP-75-1. This report considers that a reduction in air carrier landing accidents can be achieved with ILS equipment providing service in IFR weather conditions only. However, it is the opinion of the National Transportation Safety Board (NTSB) as well as a number of operational people within FAA that precision guidance is of equal importance in reducing landing accidents during VFR, particularly at night and in marginal visibility. Precision guidance is considered to be an all-weather service by all



* APPROACHES MADE UNDER INSTRUMENT FLIGHT RULES AND IN INSTRUMENT METEOROLOGICAL CONDITIONS

Figure 6. Estimated Use of Available
ILS for Equipped Aircraft by Weather Category, User Group, Flight Rule.

users of the National Airspace System (NAS). Therefore, the exclusion of those landing accidents in VFR weather that could have been prevented by the use of an ILS results in a conservative estimate of the dollar amount of safety benefits to be derived.

Another critical assumption made by the study in estimating the dollar amount of incremental ($MLS-$ILS) benefits is the assignment of a binary benefit; i.e., all installations, ILS or MLS, providing full CAT-I service received the safety benefits estimated for precision guidance equipment; those installations providing restricted service are assigned zero-dollar benefits. This binary assignment is supported by the operational consideration that, in the future period involved in the study's planning horizon, all precision guidance approaches will be made the same way regardless of weather conditions. Further, all aircraft will be required to remain on the glide slope until they reach an appropriate height that is not weather dependent. The ultimate goal of precision guidance service is envisioned to be one of providing fully automatic landing capability. As a matter of practice for the future planning period under consideration, the appropriate height for all precision approaches will be considerably less than the present CAT-I service height of 200 feet. Hence, all ground installations providing service at less than this height with either ILS or MLS will offer less than the full quota of safety available from a full, unrestricted signal. The restricted installations were, therefore, estimated to provide zero ILS benefits if unrestricted service could be provided by the MLS at the same location.

The assignment of zero-dollar benefits for restricted ILS or MLS locations is not intended to reflect the opinion that these types of operations are unsafe. They are much safer than nonprecision approaches. But, they are surely less safe than using equipment with no restrictions in service. Some precision guidance service may be better than none, but only if alternative, non-restricted, equipment is not available, and if future landing operations are not standardized to the same automated procedure to be used independent of weather. No analytical method based on a sufficient data base currently exists for assigning partial benefits to the receipt of partial service, and in a benefit category as critical as safety it is doubtful that such partial assignments would be justified. For these reasons, the identical safety benefits designated in the installation criteria ASP-75-1 were assigned to the equipment, either ILS or MLS, able to deliver the full CAT-I service defined in these criteria; no benefits were estimated when less than full service was offered in place of an unrestricted alternative. No differential benefits were determined for the MLS on the basis of a superior quality of signal. An incremental safety benefit was assigned to MLS solely on the basis of more locations being able to provide full, unrestricted service. A summary of incremental (MLS-ILS) safety benefits accruing to the aviation user operating over a network of 1250 ground installations is shown in figure 7 in constant-value 1976 dollars, discounted at a rate of 10 percent over a 20-year program life to the start of the program.

A more detailed break-out of the extra safety benefits provided by MLS equipment, distributed according to user category and airport location, is shown in table 2. Note that the largest user category benefitting from increased safety is the general aviation user group (46 percent); these benefits are greatest at the small community airports, many of which will be newly qualified to receive precision guidance service by the year 2000.

TABLE 2. INCREMENTAL SAFETY BENEFITS (MLS-ILS) BY
AVIATION USER CATEGORY AND AIRPORT TYPE
(IN MILLIONS OF 1976 DOLLARS, DISCOUNTED AT 0.10)

	AIRPORT TYPES*				
User Category	A Major Airport	B Medium Airport	C Small Community Airport	D Small; New Qualifier	Total
Air Carrier	7.7	2.9	0.9	--	11.5
Commuter	0.6	0.6	1.4	0.6	3.2
Gen'l Avtn. Corp. Jet	0.1	0.3	0.8	1.2	2.4
Mult. Prop.	0.1	0.5	1.3	2.0	3.9
Sing. Prop.	0.2	1.7	4.2	6.5	12.6
	8.7	6.0	8.6	10.3	33.6

Ref: Vol. I App. C
Tables 7-A thru 7-D

*Described on page (9).

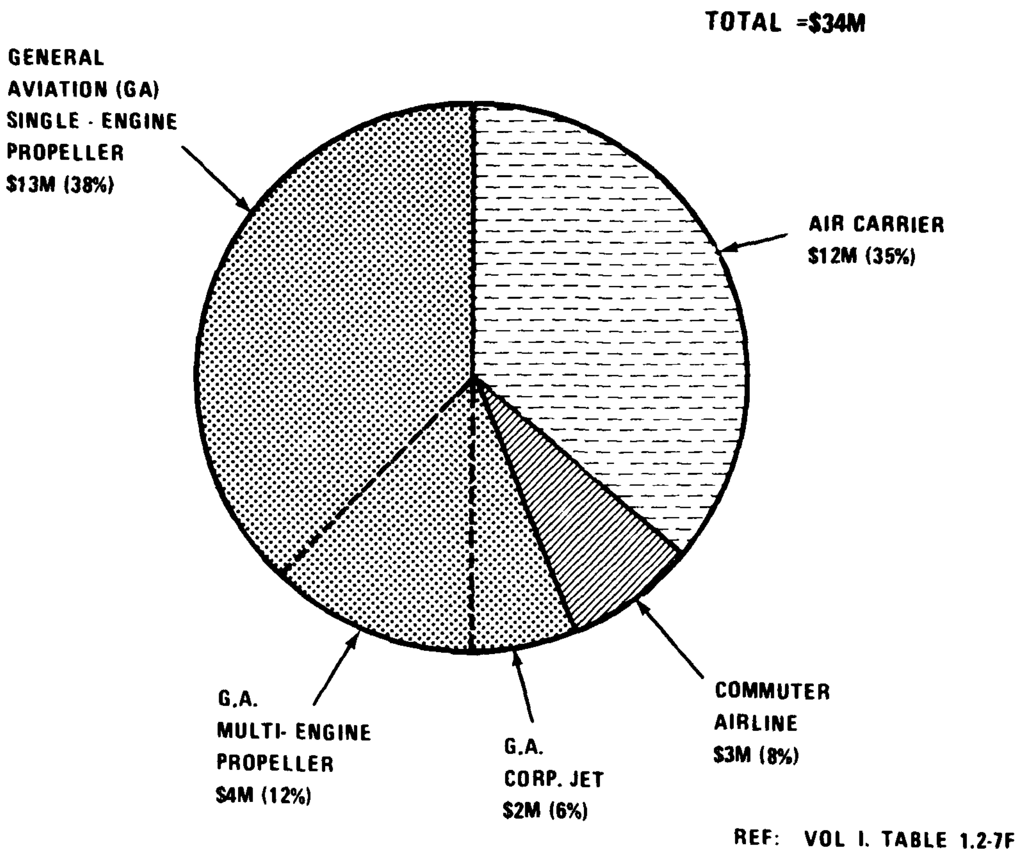


Figure 7. Incremental (MLS-ILS) Safety Benefits, by Aviation User Groups. (In Millions of 1976 dollars, discounted at 0.10).

2. Determination of Flight Disruption Benefits (Alleviation of Delays Diversions and Cancellations Due to IFR Weather). This benefit derives from the avoidance of a flight disruption due to the inability to complete a landing in Instrument Meteorological Conditions (IMC). The guidelines contained in FAA Report No. ASP-75-1 for estimating these benefits were strictly adhered to. The dollar values of avoiding flight disruptions were based upon the 1975 median income levels for air passengers. These data were updated to reflect the increased dollar value of time lost, due to higher (median) passenger incomes earned during the future program planning horizon.

In estimating the benefits for reduced flight disruptions, there was no "all or nothing" (binary) assignment depending upon whether a system was able to provide unrestricted service. Those locations determined as being restricted to above CAT-I levels were estimated to contribute to flight disruptions only when the weather minimums were below available service levels. In effect, then,

in estimating the benefits from avoiding flight disruptions, all gradations of restrictions were viewed as providing a partial benefit for a specific interval of weather conditions. A three-way classification scheme of grading the level of restrictions of ILS ground installations -- low, medium, and high -- was developed for the study according to the following definitions:

- Low Restrictions - Interval of service from 200 feet by 1/2 mile to 300 feet by 1/2 mile. Out of 153 installations surveyed and found to be restricted, 106 were estimated to be in this interval.

- Medium Restrictions - Interval of 300 feet and 1/2 mile to 800 feet and 2 miles. Some 47 ground systems were surveyed and estimated to be in this interval.

- High Restrictions - Interval in excess of 800 feet and 2 miles. Nine installations currently commissioned were estimated to be in this interval. In addition, there are other locations considered eligible for precision guidance service, but which cannot be offered this service with ILS equipment. Some 17 additional locations are included in this category.

The distribution of ILS-restricted locations, based on the data presented above, was estimated to be 62-percent Low, 28-percent Medium, and 10-percent High. This distribution was estimated to hold for future ground-system installations. The same value for avoiding a disruption was assigned to both ILS and MLS. An incremental benefit was assigned only to those additional locations currently or projected to be restricted with ILS, and estimated to provide full service, to levels of CAT I, II, or III, with MLS. Flight disruption benefits were determined by estimating the effect that national averages of weather conditions would have on those locations where the level of service could be improved with MLS.

A summary of the incremental (MLS-ILS) flight-disruption benefits accruing to a national network of 1250 ground installations is shown in figure 8, in 1976 constant value dollars discounted at a rate of 10 percent over a 20-year program period. The largest user category is shown to be the Air Carrier with some 80 percent of the total of $277 million in accrued benefits; some 40 percent of this amount is generated by savings in passenger time.

3. Reduction in Arrival Delays Due to System Outages. This benefit derives from the reduction in the frequency and duration of equipment outages estimated for the MLS. Because the MLS does not require a ground plane, systems outages due to geophysical changes on the surface (snow, soil moisture, tides) will be minimal or nonexistent. In addition, the expected design specification for MLS equipment will require that it achieve a Mean-Time-Between-Failures (MTBF) approximately twice that estimated for modern solid-state ILS equipment. The Mean-Time-to-Repair system outages, designated by design specifications for the MLS will also be significantly improved to 30 minutes.

The effects of these MLS improvements were estimated for Chicago's O'Hare Airport (ORD), based upon a detailed record of equipment outages and associated delays recorded at this airport over recent 3-month period. It was determined that 1 percent of the delays forecast for this airport could have been avoided

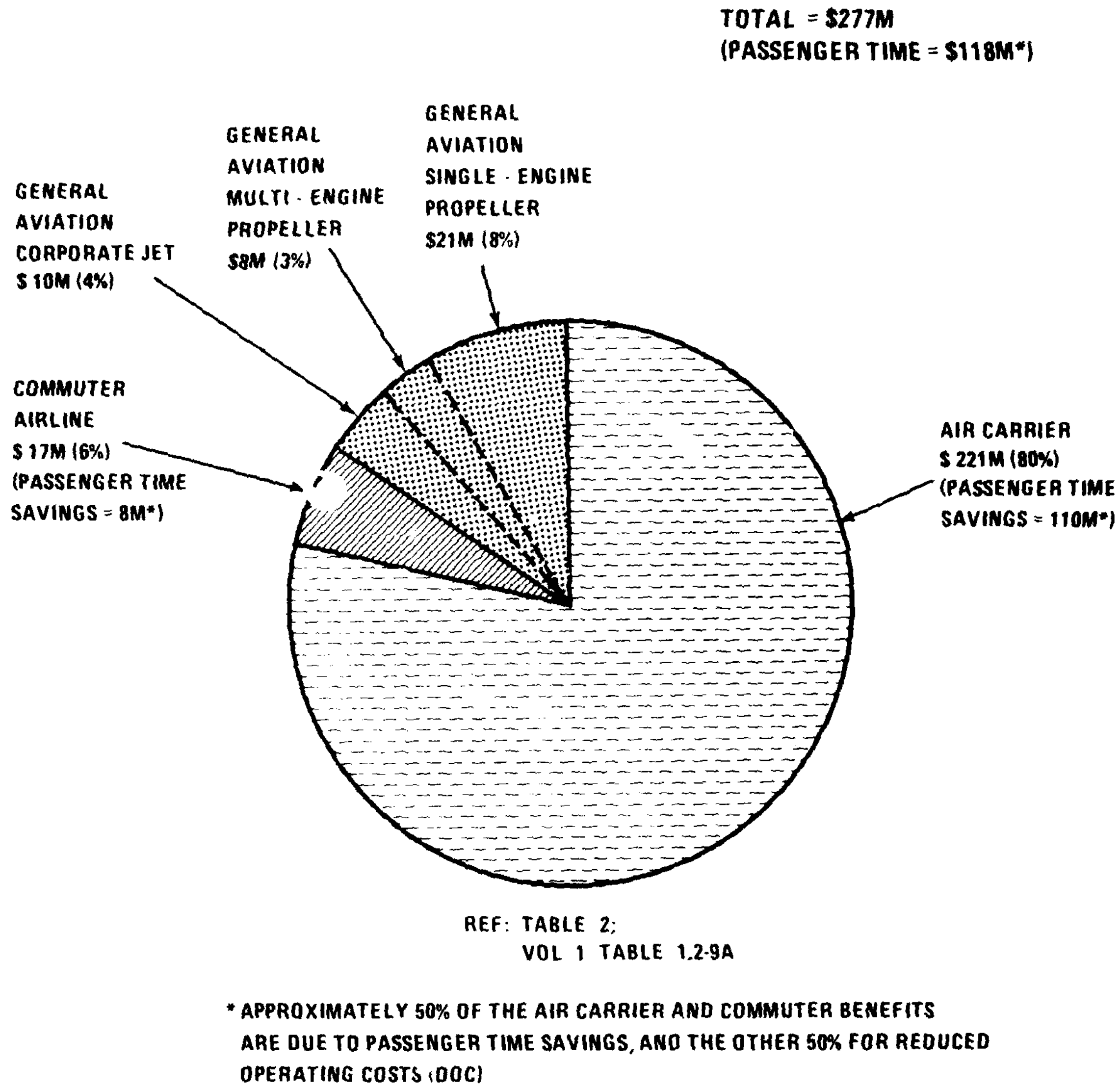
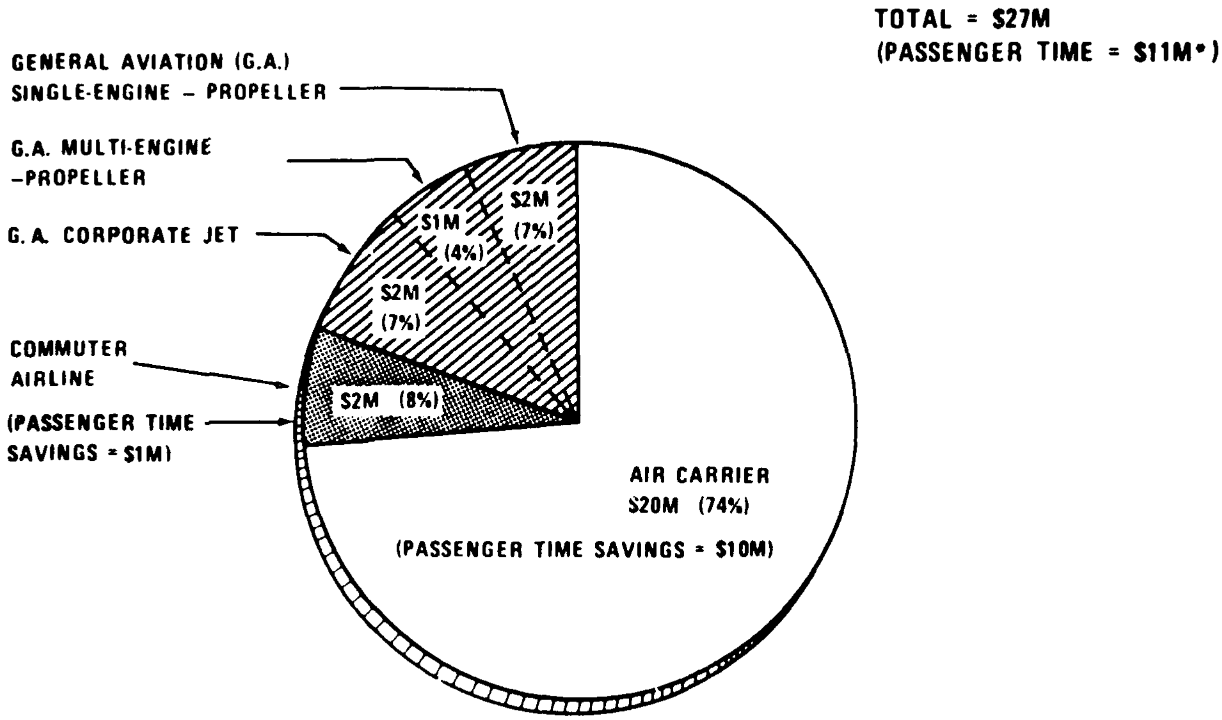


Figure 8. Incremental (MLS-ILS) Flight Disruption Benefits, by Aviation Use Group, (In Millions of 1976 Dollars, Discounted at 0.10).

with the less environmentally sensitive, more reliable and easily maintained, MLS equipment. A similar savings of 1 percent in delays was calculated for aircraft operations at the top 40 (type A) major airports. The forecast of delays used in these calculations was obtained from the estimates of improvements in annual delays at major airports reported in a recent study of the Upgraded Third Air Traffic Control System (UG3RD).[4]

A summary of the incremental ($MLS-$ILS) benefits resulting from a national network of 1250 ground installations is shown by figure 9 in 1976 *constant-value*

[4]"An Overview and Assessment of Plans and Programs for the Development of the Upgraded Third Generation Air Traffic Control System," FAA-EM-75-5; March 1975.



* APPROXIMATELY 50% OF THE AIR CARRIER AND COMMUTER BENEFITS ARE DUE TO PASSENGER TIME SAVINGS, AND THE OTHER 50% FOR OPERATING COSTS (DOC)

Figure 9. Incremental (MLS-ILS) Reduction in Arrival Delay Benefits Due to System Outages by Aviation User Group, (In Millions of 1976 Dollars, Discounted at 0.10).

dollars discounted over a 20-year program life to the start of the program. The major beneficiary of reduced delays due to system outages is identified as the Air Carrier user group with 74 percent of the total of $27 million in benefits; about half of these Air Carrier benefits accrue to the airline passenger.

4. Reduction of Delays From Removal of Ground and Airspace Restrictions. Findings at three of the five case-study airports (JFK, LGA and DCA) indicated that dollar benefits would accrue to MLS through removal or reduction of ground

and airborne restrictions to aircraft movements currently experienced with ILS at these airports. A benefit of $206-million (in discounted dollars valued at 1976 levels) over the program life was determined for the Air Carrier user group ($103 million for passenger-time savings) operating out of these major type A airports. This savings includes an estimated 330-million gallons of fuel.

5. Reduced Approach-Path Lengths. This benefit derives from the potential reduction in flight times made possible by precision guidance along a curved path provided by MLS equipment. Based upon the results of a questionnaire received from airport operators, a current and future need for curved approaches was determined. In conjunction with this questionnaire, an estimation was made of path reductions in the approaches made by the Air Carrier user group to both the top 40 (type A) major airports and to approximately 25 percent of the medium hub (type B) airports that would be equipped with appropriate MLS capability. The calculated savings in flight-time for Air Carriers due to path reductions were $104 million in discounted dollars at type A airports and $23 million at type B airports, for a total of $127 million; $63 million of this total accrues to the passenger as time savings. The total projected fuel savings is 209 million gallons.

6. Summary of Dollar Benefits. A summary recapitulation of all dollar benefits is shown in table 3 for a national network of 1250 MLS installations. The amounts shown are in constant-value 1976 dollars, discounted at a rate of 10 percent to the start of the program.

When these incremental benefits due to MLS are compared with the additional MLS costs to the users of the national system, including the FAA, there is sufficient information available for making an economic evaluation of a program to implement MLS equipment. A discussion of the cost estimates follows in subsections G and H.

TABLE 3. SUMMARY OF INCREMENTAL BENEFITS
BY BENEFIT CATEGORY FOR INDIVIDUAL USER GROUPS
(IN MILLIONS OF 1976 DOLLARS; DISCOUNTED AT 0.10)

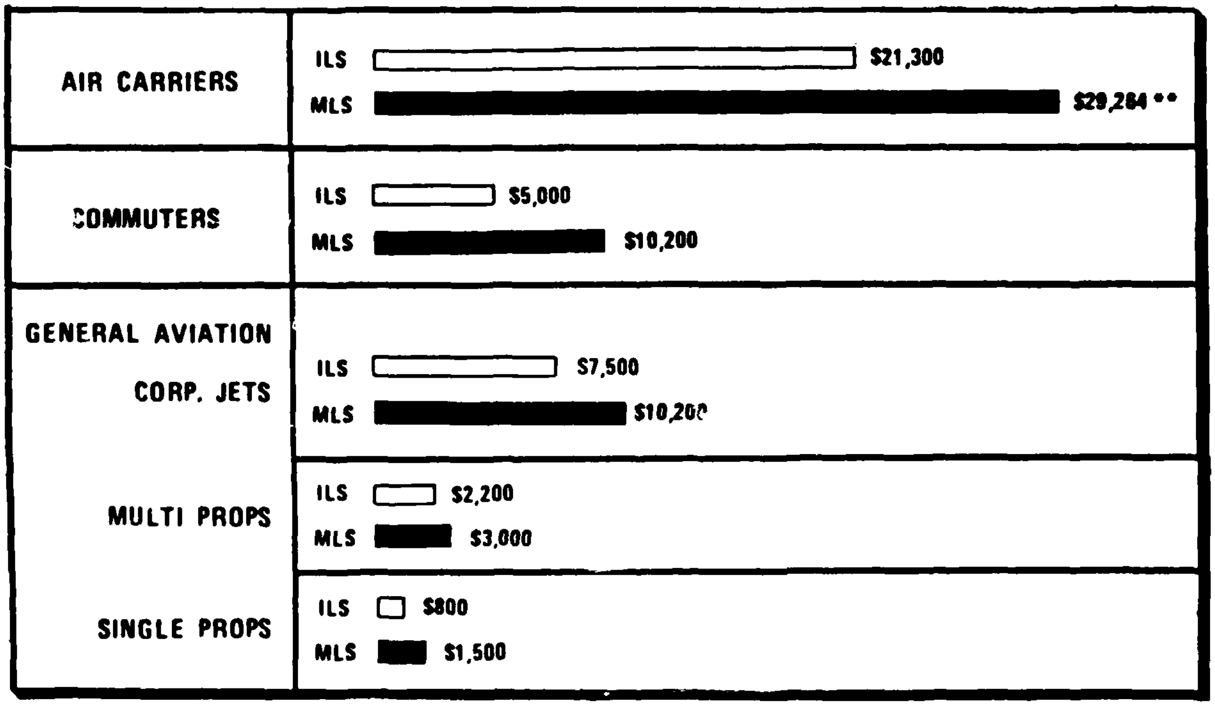
USER GROUP	IMPROVED SAFETY	REDUCED FLIGHT DISRUPTION	DELAY SAVINGS		PATH-LENGTH REDUCTION	TOTAL
			OUTAGES	AIR AND GROUND RESTRICTIONS		
Air Carrier	$12	$221	$20	$206	$127	$586
(Passenger Time)	--	($110)	($10)	($103)	($ 63)	($286)
Commuters	3	17	2	--	--	22
(Passenger Time)		(8)	(1)	--	--	(9)
General Aviation*						
Corporate Jet	2	10	2	--	--	14
Multi-Engine Prop	4	8	1	--	--	13
Single-Engine Prop	13	21	2	--	--	36
All Users	$34	$277	$27	$206	$127	$671
(Passenger Time)	--	($118)	($11)	($103)	($ 63)	($295)

*Includes air taxi

G. AVIATION USER COSTS

The avionics costs to each aviation user group was estimated for the component categories of (1) investment, and (2) operation and maintenance costs.

1. Investment Costs for Avionics. The costs for unit installation of ILS and MLS avionics, including dual equipage where required, are shown in figure 10. The percent avionics equipage by user category for precision guidance is estimated as shown in figure 11.



*Dual Avionics for all Aircraft Except Single-Props

**Includes Cost of Computer for Precision Curved Approaches

Figure 10. Differences in Unit Avionics Systems Cost per Aircraft* by User Group in 1976 Dollars.

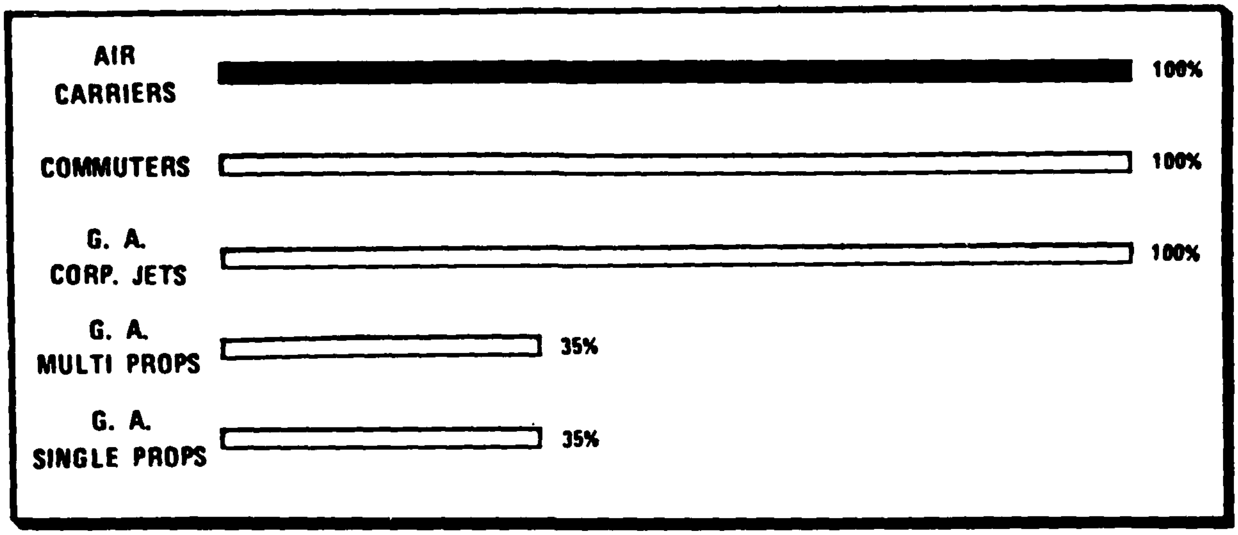


Figure 11. Estimate of Avionics Equipage for Precision Guidance.

Predictions of fleet sizes were obtained from official FAA forecasts for the list of aviation user groups, and a comparison was made of the costs to implement each user group's fleet with ILS or, alternatively, with dual ILS and MLS equipment until the end of the transition period. The following assumptions were made in determining fleet costs for ILS and MLS.

- For the "ILS Continuation Program Option":
  - ILS avionics equipment would continue to be retired and replaced at a normal rate after a useful life estimated at 15 years.
  - All aircraft entering the fleet in accordance with official FAA forecasts would receive new ILS avionics estimated to last 15 years installed in accordance with the percentages shown in figure 11.
  - The ILS avionics fleet will require a retrofit conversion to a 50-kHz channel separation in order to defer a problem of ILS channel congestion. It was estimated that the conversion would have to be completed by 1988, assuming a national requirement of 1250 ground installations by the year 2000. The unit costs to convert ILS avionics for those aircraft not presently equipped with 50-kHz frequency channel separation were estimated as shown in table 4.

TABLE 4. ESTIMATE OF ILS UNIT AVIONICS CONVERSION COST

USER GROUP	UNIT COST
* Air Carrier	$10,000
Commuter; Corporate Jet	4,000
General Aviation Prop * (50% of fleet already converted)	1,800

- For The MLS New Implementation Program Option:
  - MLS avionics investment costs include the full costs needed to implement the fleet with ILS avionics during the transition period. Thus, the costs to replace retired ILS avionics plus the ILS costs for equipping the new aircraft entering the fleet are charged to the MLS implementation program costs for the full length of the transition period, nominally estimated as 10 years.

  - MLS avionics equipage is assumed to be zero at the start of the program in the year 1980 and to build to the identical ILS fleet equipage level by the end of the transition period. After this date, MLS avionics will be implemented to satisfy the requirement for new aircraft entering the fleet in accordance with FAA forecasts; replacement of MLS avionics to take place after a useful life estimated at 15 years.

- The incremental avionics investment costs ($MLS-$ILS) were calculated by estimating the MLS investment costs (MLS plus redundant ILS avionics cost burden until the year 1990) and subtracting the ILS costs for the years 1980 through 2000.

A summary presentation of incremental avionics investment costs is shown in the left hand column in table 5, categorized by user group. Note that a major portion (38 percent) of the ILS investment costs shown in this table are necessary to convert equipment to avoid the problem of channel congestion. On the other hand, $103 millions out of a total of $365 millions (28 percent) required to invest in MLS avionics are required to maintain the ILS system during the transition period. After this period, indeed, even beyond the year 2000, MLS avionics costs will compare more favorably to the ILS.

2. Operation and Maintenance Costs for Avionics. The annual costs to Operate and Maintain (O&M) a unit of avionics, either ILS or MLS, are shown in figure 12. These costs include the additional costs to the ILS for unverified removals. The ability to make more accurate diagnoses of equipment failures with MLS results in a reduction in the incremental avionics O&M costs for air carriers, commuters, and the corporate jets included in the general aviation fleet.

The comparative program or total system costs to operate and maintain a fleet of ILS equipped aircraft, or alternatively, MLS-equipped aircraft, can be calculated from the following rules similar to the ones described for investment costs:

- ILS O&M costs are determined by the total aircraft fleet size, per user group, multiplied by unit O&M costs per aircraft shown in figure 12.

• MLS O&M costs during the transition period will include the estimated "ILS Continuation Program Option" costs for this period. Thus, the costs to maintain a fleet of ILS-equipped aircraft will be carried as a redundant burden to the MLS for a nominal transition period of 10 years. After full replacement of ILS equipment has been made for existing aircraft plus forecast additions to the fleet, the incremental costs, MLS-ILS, will be a simple subtraction of costs for the posttransition period; the remainder of the 20-year program planning horizon. The calculation of total 20 year program costs for O&M is shown in the right-hand column in table 5, categorized by user group.

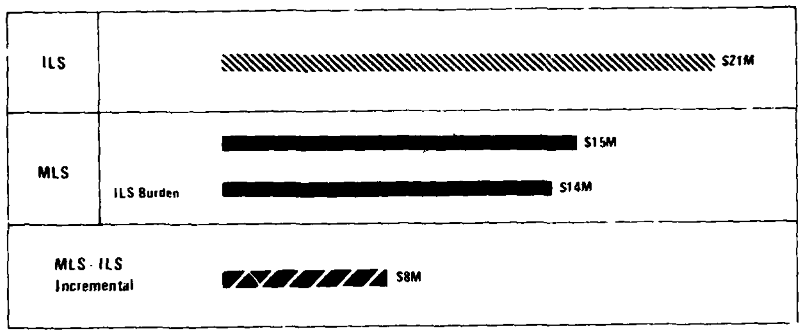


Figure 12A. Total of Avionics Operating (O&M) Costs For Air Carriers (in Millions of 1976 Dollars, Discounted at 0.10)

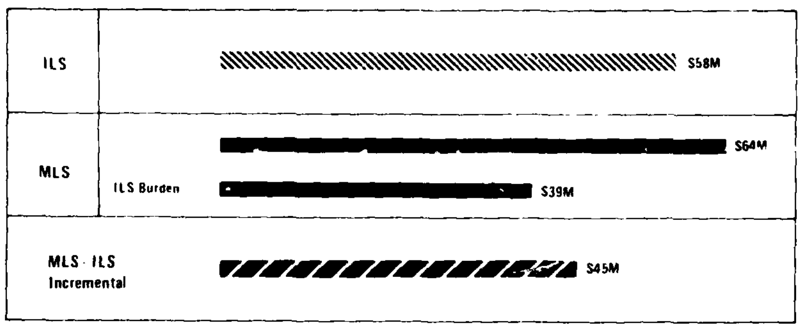


Figure 12B. Total of Avionics Operating (O&M) Costs For All Users (in Millions of 1976 Dollars, Discounted at 0.10)

Table 5 indicates the costs to maintain avionics are not very different ($58 million for the ILS; $64 million for MLS) if the burden of maintaining the ILS were not charged as costs to the MLS during the transition period. Some of the $39 million in ILS burden could be avoided by a delay or postponement in the purchase of redundant sets of avionics equipment, particularly by the aircraft owners using precision guidance service for the first time.

TABLE 5. TOTAL OF AVIATION USER AVIONICS COSTS
INVESTMENT AND OPERATING (O&M) BY USER GROUP
(IN MILLIONS OF 1976 DOLLARS, DISCOUNTED AT 0.10)

I.	INVESTMENT		OPERATING (O&M)		TOTAL
ILS	New Equip.	Freq. Conv.			
Air Carrier	53M	8M	21M		82M
Commuter	5M	3M	2M		10M
G.A.					
Corp. Jet	35M	14M	9M		58M
Mult. Prop	16M	9M	4M		29M
Sing. Prop	38M	56M	22M		116M
Total: G.A.	89M	79M	35M		203M
TOTAL: ILS	147M	90M	58M		295M
II. MLS	New Equip.	ILS Burden		ILS Burden	
Air Carrier	84M	37M	15M	14M	151M
Commuter	11M	3M	2M	1M	17M
G.A.					
Corp. Jet	57M	25M	11M	6M	99M
Mult. Prop	26M	11M	5M	2M	44M
Sing. Prop	84M	27M	31M	16M	157M
Total: G.A.	167M	63M	47M	24M	300M
TOTAL: MLS	262M	103M	64M	39M	468M
III. MLS-ILS Incremental					
TOTAL:	128M		45M		173M

Ref: Vol I App H, I.

3. <u>Summary of Avionics Costs Incremental to MLS.</u> The added costs of $173 million accumulated over a 20 year program period and discounted at a rate of 10 percent are pictorially shown in figure 13 distributed according to category of use. The major share of the additional costs for MLS avionics (40 percent) is expected to be borne by the Air Carrier.

H. FAA COSTS (GROUND EQUIPMENT)

The ground installation costs accruing to the FAA as owner and manager of the precision guidance facilities and equipment are described in the following paragraphs. Component costs are provided in the separate categories of: (1) investment costs and (2) operation and maintenance (O&M) costs.

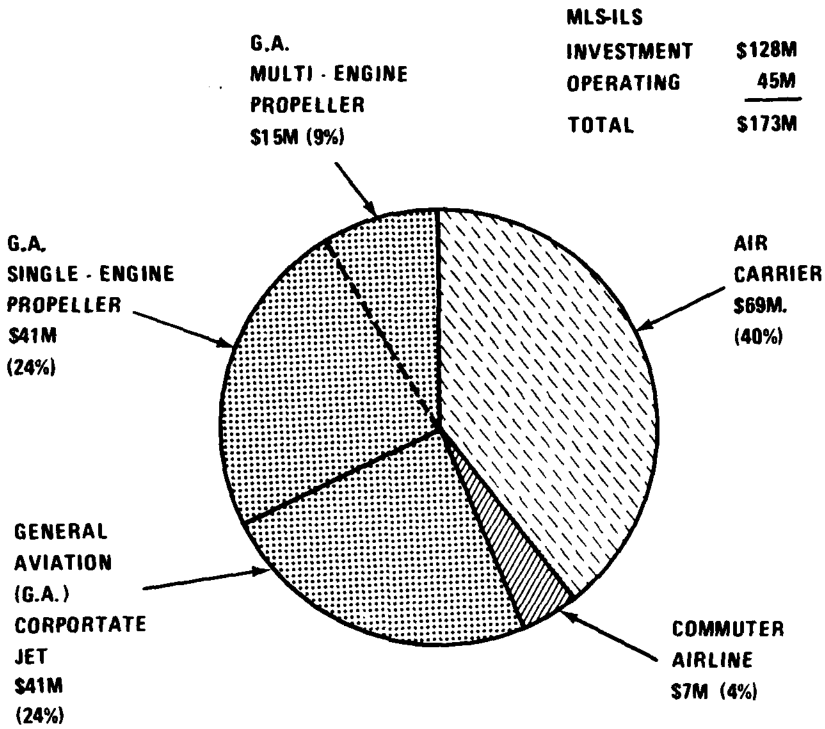


Figure 13. Incremental (MLS-ILS) Avionics Costs Investment and Operating, by User Group, (In Millions of 1976 Dollars, Discounted at 0.10).

1. Investment Costs for ILS and MLS Ground Equipment. The method for estimating the comparative costs for ground installations is similar to the one used to determine avionics costs. The following rules and procedures were employed.

- An inventory was made of present ILS installations categorized by airport types (A through D) and level of service (CAT I II, or III).
- A forecast of future requirements was made by airport type and service level to a total of 1250 ground systems by the year 2000.
- MLS installations were estimated to be zero at the start of the program in 1980 and to build, at a linear rate of implementation, to the identical number of ILS systems estimated to be in place by the end of the transition period; nominally estimated as the year 1990.
- No deterioration in service is estimated to occur during the transition period since the present inventory of ILS installations plus those newly qualified for precision guidance service until the start of the program are assumed to remain as a redundant or parallel system to the MLS. The costs for maintaining this redundancy during the transition period are charged to the MLS program alternative.

a. <u>Ground Investment Costs for ILS Program</u>. The investments required for implementing an ILS network of 1250 ground installations by the year 2000 include:

- Unit ground equipment costs for original installation, or, upgrading equipment from a lower service level.
- Site preparation costs.
- Replacement of vacuum tubes with solid-state equipment.
- Conversion of channel frequencies to 50-kHz separations.

The number of installations having vacuum-tube electronics (approximately 350) was determined from the inventory of present ILS ground equipment. These installations were estimated to be modified to solid state at a linear rate by the end of the transition year. All new ILS equipment installed was assumed to be solid-state.

The cost for frequency changes to ground systems ($25,000 per installation for two required changes) as a result of conversion to 50-kHz channel separation (20 to 40 channels) was estimated to occur in 1988, when the 930th ground installation is forecast to be made.

The unit investment costs required for ILS ground installations are presented here for two illustrative examples of airport type and service levels: Example 1 is for type A airport locations equipped to CAT I. Example 2 is for type B airports equipped to CAT II.

The calculations of total ILS investment costs for each year of the 20 year program horizon, for all airport types and service levels, can be found in Volume I, tables 1.3-23 through 1.3-31.

<u>Example 1: Unit ILS Ground Investment Costs, Airport Type A, CAT I ($1976)</u>

Ground Equipment:		
Original Installation		$222,900
Site preparation:		
Nominal	75%	90,000
Difficult	25%	230,000
Solid-State Replacement		222,900
Frequency Change		25,000

Example 2: Unit ILS Ground Investment Costs, Airport Type B, CAT II ($1976)

Ground Equipment:		
Original Installation		$417,000
Upgrade from CAT I		417,000
Site Preparation:		
Nominal	75%	152,000
Difficult	25%	350,000
Upgrade		62,000
Solid-State Replacement		---
Frequency Changes		25,000

b. Ground Investment Costs for MLS Program Alternative. The estimation of unit MLS ground investment costs does not include costs for site preparation, frequency changes, vacuum tube replacement, or upgrading. These costs are included in the original investment price for MLS equipment shown in table 6 for various airport types and service levels.

The study estimated that type A airport locations would be completely (100 percent) equipped with the Basic MLS and that those type B locations estimated as being upgraded to CAT II levels by the year 2000 would be equipped with the Basic MLS. All other airport type B locations would receive the Small Community MLS (SCMLS). Airport types C and D locations would be completely (100 percent) equipped with the SCMLS.

2. Operation and Maintenance (O&M) Costs for ILS and MLS Ground Equipment. The annual cost to operate and maintain a ground installation, ILS or MLS, depends upon the level of service being implemented at a given airport type. Annual O&M costs (including flight inspection costs) per installation are shown below for the following example illustrations of: (1) type A airport locations equipped to CAT I levels, and (2) type B airport locations equipped to CAT II levels. Similar O&M cost estimates for all service levels are shown in table 6.

Example 1: Unit Annual O&M Costs, ILS vs MLS Airport Type A, CAT I ($1976)

ILS:	Solid State	$27,000
	Vacuum Tubes	43,000
MLS:	Basic Model	$24,000

Example 2: Unit Annual O&M Costs, ILS vs MLS Airport Type B, CAT II ($1976)

ILS:	Solid State	$56,000
MLS:	Basic Model	$31,000

TABLE 6. UNIT ILS AND MLS GROUND COST COMPARISONS (THOUSANDS OF DOLLARS)
($ 1976)

ILS GROUND INSTALLATION	CAT I	CAT II	CAT III
Investment Costs	$222,900	$417,000	$740,000
Site Preparation Costs			
• Nominal	90,000	$152,000	$152,000
• Difficult	230,000	350,000	350,000
O&M Costs†			
• Solid State	$ 27,000	$ 56,000	$ 65,000
• Tube	43,000	--	--
Flight Inspection Costs			
• Periodic	$ 7,250	$ 7,250	$ 7,250
• Nonperiodic	1,924	1,924	1,924
MLS Ground Installation	**CAT I**	**CAT II**	**CAT III**
Investment Costs*	$310,410 (Basic) $214,125 (SCMLS)	$495,000	$860,000
O&M Costs†			
• Current Maintenance Concept	$ 24,000 (Basic) 18,000 (SCMLS)	$ 31,000	$ 46,000
• Centralized Maintenance Concept	$ 17,000 (Basic) $ 12,000 (SCMLS)	$ 24,000	$ 30,000
Flight Inspection Costs			
• Periodic	$ 3,600	$ 3,600	$ 3,600
• Nonperiodic	--	--	--

*Site preparation costs are included in investment costs.
†O&M costs include flight inspection costs.

The O&M costs shown are based upon the present concepts and procedures for maintaining ground equipment, including prescribed flight inspections. However, with MLS equipment the opportunity exists to use a centralized monitoring concept having remote diagnostic capability. By employing this concept, the O&M costs for MLS could be reduced by some 20 to 30 percent below the costs shown in table 6, and included in the study.

3. Summary of ILS and MLS Programs Ground Costs. The unit investment costs, discussed in the preceding section, must be multiplied by the number of installations required each year in order to determine annual investment costs. The unit O&M costs must, likewise, be multiplied by the number of existing installations in order to determine annual operating costs. The inventory and resultant costs for installations in place for any given year were determined from a detailed set of requirements for precision guidance equipment drawn for all airport type locations and service levels.

An illustrative example of the inventory of installations for major type A airport locations equipped to CAT I service levels is shown in table 7. Similar lists of the present inventory and future ground installations for all airport types and service levels are to be found in Appendix K, Volume I. All tables of ground systems to be commissioned by the year 2000, by airport type and service level, have the common characteristics of: 1) a linear build-up of the MLS to parity with the ILS by the year 1990, 2) both ILS and MLS meeting a National requirement for 1250 ground systems by the year 2000.

The reader's attention is directed to the summary column of table 7 which indicates that there will be 12 additional runways at type A airports by the year 2000 that can deliver full, unrestricted, CAT I service with MLS ground equipment in place of ILS. It is this difference in numbers of installations providing full service with MLS compared to ILS that accounts in a significant way for the incremental benefits accruing to the MLS system, and shown in table 3.

Table 8 is a summary of the investment and operating costs for a National network of 1250 ground systems to be managed by the FAA under the alternative program options of ILS or MLS. Despite the fact that $132 million of the total MLS operating costs of $257 million (51 percent) are required to maintain the ILS until the end of the transition period, the potential savings in total program costs over a period of 20 years and discounted at a rate of 0.10, is shown as $40 million; these savings are about evenly divided between investment costs ($18 million) and operating costs ($22 million).

TABLE 7. GROUND SYSTEMS TO BE COMMISSIONED FROM PRESENT LEVELS TO PLANNED REQUIREMENTS BY YEAR 2000

Service Level - CAT I
Airport Type A - Large hub air carrier airports (total of 40 airports)[1]

1250 System Total Network Requirement

	ILS REQUIREMENT LEVEL				MLS REQUIREMENT LEVEL		
	INVENTORY	FORECAST			FORECASı		
	1976	1980	1990	2000	1980	1990	2000
(1) Installations in Place	(63 to be Upgraded to CAT.II)				(63 to be Upgraded to CAT.II)		
Meets CAT I	65	82	50.5	19	0	50.5	19
Restricted*	16	20	20	20	0	12	12
Restriction Removed	--	--	--	--	0	8	8
Total	81	102	70.5	39	0	70.5	39
(Tube Types)**	(57)						
(2) To be Installed	(New Qualifiers: 1980 - 2000)				(New Qualifiers: 1980 - 2000)		
Meets CAT I	--	0	15.5	31	0	15.5	31
Restricted		0	5	10	0	3	6
Restriction Removed		--	--	--	0	2	4
Total		0	20.5	41	0	20.5	41
(3) Summary for Year 2000							
Total Planned				80			80
Meets CAT I				50			50
Restricted				30			18
Restriction Removed				--			12

[1]Other airport types and CAT levels are shown in Appendix K, Vol. I.

*Determined from existing ILS data, includes ILS which have signal-in-space problems (see Appendix L, Volume I).

**All vacuum tube installations in place by year 1980 to be replaced by the end of the transition year 1990.

Table 8. Total of FAA Program Costs, Investment and Operating for 1250 Ground Systems (In Millions of 1976 dollars, discounted at 0.10)

	INVESTMENT	OPERATING	TOTAL
ILS			
New Equip.	102M		
Site Prep.	50M		
Tube Mod.	32M	Solid St. 230M	
Cat. Upgrade	43M	Tubes 49M	
Freq. Conv.	2M		
	229M	279M	508M
MLS			
Basic Equip.	129M	69M	
Small Comm. Equip.	82M	56M	
ILS Burden	--	132M	
	211M	257M	468M
MLS-ILS Incremental	* (-) 18M	(-) 22M	(-) 40M

* (-) indicates a savings with MLS.

Ref: Vol I. Table 1.3 - 31
Table 1.3 - 41

Table 9 provides a more detailed computer print-out of incremental, MLS-ILS, ground system costs categorized by airport type and service level.

The incremental costs shown in table 9 confirm the intuitive notion that the currently installed ILS system will be favored under present-day operational requirements. The investment in CAT I equipment has already been undertaken to a large extent at existing airport type A and B locations. Thus, the incremental costs do not favor the MLS at these locations. However, as requirements are estimated to grow in the future to the higher service levels of CAT II and CAT III, and as more type C and D airports (small community types) are equipped with precision guidance, the incremental costs become negative, indicating a favorable turn to MLS equipment. The total of negative incremental costs is for $40 million for all airport types and service levels implemented over a period of 20 years, and discounted at a rate of 0.10.

Finally, it is important to note that for every airport type and service level, there is a net MLS savings (minus sign) to the FAA for all individual years following the end of the transition period in 1990. After the transition, net savings begin to accrue to the MLS and continue until the end of the planning period in the year 2000 and beyond. But, the effect of "discounting" is to diminish the size of these potential savings because they occur in the later years of the program evaluation period. On the other hand, the MLS "burden" of maintaining existing ILS installations, predominantly CAT I equipment

TABLE 9. GROUND SYSTEM COSTS, 1250 SYSTEMS

TOTAL OF INVESTMENT AND OPERATING

ALL AIRPORTS, ALL SERVICE LEVELS

INCREMENTAL (MLS MINUS ILS) COSTS IN ACTUAL DOLLARS

YEAR	TYPE A CATEGORY I	TYPE A CATEGORY II	TYPE A CATEGORY III	TYPE B CATEGORY I	TYPE B CATEGORY II	TYPE C CATEGORY I	TYPE D CATEGORY I	TOTAL
1981	683838.	-1288646.	-367249.	315731.	-2961477.	2296384.	-535404.	-1856816.
1982	1023138.	-1320646.	-371949.	853730.	-3128976.	3248976.	-569154.	-264848.
1983	1362437.	-1352647.	-376649.	1391730.	-3296477.	4201584.	-602904.	1327088.
1984	1701737.	-1384647.	-381349.	1929730.	-3463976.	5154176.	-636654.	2919024.
1985	2041036.	-1416646.	-386049.	2467730.	-3631476.	6106800.	-670404.	4511008.
1986	2380337.	-1448646.	-390749.	3005730.	-3798977.	7059376.	-704154.	6102944.
1987	2719637.	-1480646.	-395449.	3543730.	-3966476.	8011968.	-737904.	7694896.
1988	3054627.	-1583897.	-417648.	3929230.	-4231477.	8794576.	-865404.	8680032.
1989	3346988.	-1615895.	-422349.	4467231.	-4398975.	9747200.	-899154.	10225040.
1990	3686286.	-1647895.	-427048.	5005231.	-4566475.	10699760.	-932904.	11817008.
1991	-397804.	-5421488.	-1860747.	-1902726.	-9281397.	-5253866.	-966654.	-25084672.
1992	-394504.	-5546488.	-1893048.	-1939925.	-9526382.	-5315072.	-1000404.	-25615824.
1993	-391204.	-5671489.	-1925346.	-1977125.	-9771382.	-5376267.	-1034154.	-26146960.
1994	-387904.	-5796489.	-1957648.	-2014324.	-10016382.	-5437472.	-1067904.	-26678112.
1995	-384603.	-5921487.	-1989947.	-2051524.	-10261382.	-5498669.	-1101654.	-27209264.
1996	-381304.	-6046488.	-2022247.	-2088725.	-10506382.	-5559866.	-1135405.	-27740416.
1997	-378004.	-6171488.	-2054547.	-2125924.	-10751366.	-5621072.	-1169154.	-28271584.
1998	-374704.	-6296489.	-2086847.	-2163125.	-10996382.	-5682267.	-1202905.	-28802720.
1999	-371402.	-6421487.	-2119148.	-2200324.	-11241366.	-5743471.	-1236655.	-29333872.
2000	-368104.	-6546487.	-2151447.	-2237524.	-11486366.	-5804670.	-1270404.	-29865008.
Total	18170432.	-74380016.	-23997424.	6208458.	-141283392.	10028083.	-18339312.	-223588352.

INCREMENTAL (MLS MINUS ILS) COSTS IN DISCOUNTED DOLLARS

TOTAL	11012163.	-22688352.	-7079715.	9225093.	-46305712.	22713056.	-6769941.	-39890944.

installed at major and medium sized airports (types A and B), is incurred during the early (low discount) program years. Despite the ILS "burden" and the effect of discounting, the cost savings that accrue to the MLS in the later years of the program are still sufficient to provide a net savings to the FAA of some $40 million.

I. SUMMARY COMPARISON OF INCREMENTAL BENEFITS AND COSTS

A summary of both the incremental avionics costs and user benefits is provided in table 10. The benefits shown were obtained from table 3 and the avionics costs for the aviation user from figure 13.

For the FAA as manager of the same number of ground installations under either the ILS or MLS program option, there is no calculation of benefits and costs required. Benefits are expressed as cost savings, as shown in table 10 by the total of $40 million in net benefits for the FAA.

The dollar amounts shown in table 10 have been accumulated over a 20-year program evaluation period and discounted at a rate of 0.10. Based solely on the benefits and costs which could be quantified, a partial representation of actual conditions affecting the consideration of a new investment opportunity, the study reached the following conclusions. These are described below, separately, for 1) the Aviation User, and (2) the FAA.

J. ECONOMIC ANALYSIS CONCLUSIONS

1. For the Aviation User. Net benefits are defined as the total of program benefits minus program costs. There is a net benefit to the community of aviation users resulting from the implementation of an MLS program. The consensus net benefit for aviation users operating over a network of 1250 ground systems is $500 million. The ratio of incremental benefits to costs for the consensus of aviation users is calculated as 3.9 to 1.

The Air Carrier user group is shown as benefitting the most from the installation of the MLS as the standard for precision guidance service in place of the ILS; a benefit/cost ratio of 8.5 was estimated for this group. This ratio includes some $286 million in dollar benefits accruing to the airline passenger from a reduction in travel delays. The commuter airline user group is, likewise, shown in table 10 as having an economic advantage resulting from the implementation of MLS; a benefit/cost ratio of 2.4. This ratio includes some $9 million in dollar be[illegible] which accrue to the commuter airline passenger from a reduction in travel [illegible] The study attempted to estimate but did not include any dollar amounts for external network benefits, that is, the benefits which accrue to one aviation user group as a result of actions taken by another group. For example, a superior on-time performance by the commuter airline group using MLS, particularly in marginal weather, will result in more passengers making their major airline connections. This will increase the load factors for the major airline. The inclusion of such network effects, however, would only enhance the economic advantage that already favors the MLS for the Air Carrier aviation group.

It should be noted, however, that there is a wide disparity in the net benefits available to the individual component members of the community of aviation users. For example, the general aviation community of users is

estimated to have a net disbenefit resulting from the implementation of an MLS program. However, the size of the disbenefit to the general aviation owners of single and multi-engine propeller aircraft is quite small; a 20 year total of $2 million in discounted dollars for each category of propeller aircraft.

The study estimated that the number of aircraft in the multi-propeller fleet (General Aviation User Group B) would total 14,000 by the year 2000 and that 35 percent of these would be equipped with avionics for precision guidance. The cost to this group to: (1) replace worn-out ILS avionics equipment, (2) invest in new ILS equipment for those aircraft entering the fleet after 1980 (some 5,300 of the total fleet size of 14,000 that elected to be equipped), and (3) operate and maintain the ILS avionics equipment for a period of 20 years, was calculated as a total of $20 million in discounted dollars; see table 5. In addition, $9 million would be required to convert existing ILS avionics equipment to narrower frequency separation. The net disadvantage to this aviation user group resulting from their alternative use of MLS is estimated as $2 million, as shown in table 10. This represents some 7 percent in additional costs to the total bill of $29 million that would be expended for ILS avionics.

TABLE 10. INCREMENTAL BENEFITS AND COSTS BY USER GROUP
FOR ALL AIRPORT LOCATIONS
(IN MILLIONS OF 1976 DOLLARS, DISCOUNTED AT 0.10)

USER GROUP	INCREMENTAL BENEFITS	INCREMENTAL COSTS	NET BENEFITS*	BENEFIT/COST RATIO
Air Carrier	$586	$ 69	$517	8.5
(Passenger Time)	($286)	--	--	--
Commuter	22	9	13	2.4
(Passenger Time)	(9)	--	--	--
General Aviation:				
Corporate Jets	14	41	-27	0.34
Multi-Prop	13	15	- 2	0.87
Single-Prop	36	38	- 2	0.95
All Aviation Users	$671	$172	$499	3.9
(Passenger Time)	($295)	--	--	--
Federal Aviation Administration		-40	40	--

Note: All values rounded off.
*Net benefits equal incremental benefits less incremental costs.

For the owners of single-propeller aircraft (General Aviation User Group A) the fleet size was estimated to grow to 90,300 by the year 2000, with some 38,000 of this number being added after the year 1980, and 35 percent of this total being equipped w[illegible] precision guidance avionics. The bill to, (1) replace worn-out ILS equipment, (2) equip new aircraft entering the fleet with ILS, and

(3) maintain the entire ILS-equipped fleet, is estimated as a total of $60 million. Additional avionics costs of $56 million would need to be expended for ILS frequency conversion. An MLS economic disadvantage of $2 million, thus, represents about 1-2 percent of the total ILS avionics bill of $116 million that would be expended by this group of aircraft owners (ref. table 5).

For the owners of corporate jet aircraft (General Aviation User Group C) the assumption was made that all aircraft (100 percent) would be equipped with the same level of sophistication in avionics as those installed on the commuter aircraft; see figure 10, p.24. Thus, the study recognized the special character of this group of aviation users by the assessment of higher avionics costs, but on the benefits side no similar recognition was made of the increased value of time and convenience resulting from the special character of passenger and cargo transported in corporate jet aircraft. All owners of general aviation aircraft were estimated to value a minute's worth of aircraft delay by the amount of income they would earn in this minute. The estimated national average (median) income of all airline passengers ($25,000 per year) was assigned to all air travelers equally; airline passengers and owners of aircraft alike. It is quite obvious, however, that owners of aircraft have assets and incomes in excess of the national average. For this reason, the study's estimate of the value of time for the general aviation aircraft owner, and the dollar amount of benefits due to reduced delays that were derived from this estimate, may be significantly underestimated.

It does not take any major change in one of the study's assumptions to reverse the economic verdict which favors the "ILS Continuation" option for the general aviation user; a minor change will do. For example, the costs to maintain MLS avionics were assumed to be higher than the costs for ILS avionics. The reason for this assumption is that the purchase price for the MLS avionics was estimated to be higher (see figure 10), and an unverified "rule-of-thumb" indicates that operating and maintenance costs can be estimated by some fixed proportion (typically, 20 percent) of the equipment's original cost. Thus, based on the unit purchase price of new equipment shown in figure 10, the costs to maintain MLS avionics were estimated at a 36 percent premium for the owners of corporate jets, a 27 percent premium for the owners of Multi-Engine Prop aircraft, and a 47 percent premium for the owners of Single-Engine Prop aircraft. Since there is no logical or compelling technical reason supporting the assumption that MLS avionics will be more costly to maintain than ILS avionics, the study chose to examine the impact of eliminating the premium in maintenance costs assessed to MLS.

The alternative assumption of an equality in MLS and ILS avionics maintenance costs was examined in section 1.6, Volume I as part of the study's "Sensitivity Analysis."

The economic disadvantage to the owners of single-engine prop aircraft is reversed if the costs to maintain MLS avionics are estimated to be the same as for ILS; a negative verdict of $2 million is offset by an increase in net benefits to a total of 12 million (see table 1.6.1 in Volume I). The economic disadvantage to the owners of multi-engine prop aircraft is eliminated, and the disadvantage to the owners of corporate jets is reduced by $5 million.

Finally, another important reason for being optimistic about the acceptance of the MLS alternative by the general aviation user community, despite the marginal economic verdict rendered by the study, is the prospect for future

growth in aviation and an increased recognition of the need for precision guidance service. The study concluded that this prospect for growth in the National requirement for precision guidance service beyond the network of 1250 ground systems that were forecast, favors the implementation of the MLS. The reason for the increase in comparative economic advantage favoring the MLS is the technical limit in growth potential that limits the ILS to the ability to satisfy a National requirement that is less than 1400 installations. As the consensus economic advantage for MLS is increased for higher requirement levels, the MLS advantage to the general aviation user community is increased at a greater rate. The potential for growth beyond forecast expectations, thus, favors the general aviation users' decision to be equipped with MLS. But, most important, even for the forecast network of 1250 ground installations, the study reveals an economic advantage for the MLS in place of ILS at the small community airport, type C and D, locations. These are the airport types which have the highest proportion of runway ends that will be first-time qualifiers for precision guidance service. And, these are the airports which serve the general aviation community.

2. For the FAA User. The MLS program is estimated to provide savings in the FAA costs for implementing and operating a network of ground installations over a 20-year program planning period. These savings in discounted dollars are estimated as $40 million for a national system of 1250 installations. There are no net savings revealed for large and medium hub airports (types A and B) equipped with CAT I equipment, since the major investment in ILS equipment has already been made at these locations. The potential for significant reductions in costs to the FAA is identified, however, for higher categories of service (CAT II and CAT III) and for those airport locations (types C and D) at which major investment in precision guidance equipment have not yet been made.

Section IV

SUMMARY ASSESSMENT OF PERFORMANCE REQUIREMENTS FOR PRECISION GUIDANCE SERVICE

The benefit categories for the MLS from which the dollar amounts were derived in the Economic Analysis section were based on technical and engineering studies made in the following areas of performance requirements:

- Improvements in Major Air Carrier Airport Performance
- Relief of ILS Channel Limitations
- Federal Cost Reductions
- Upgraded Third ATC System
- Small-Community Airport Users
- Future Civil Aircraft
- Military
- International MLS Market

These performance requirements and the benefit categories derived from them are described in detail in Volume I, Chapter 2, "Technical and Performance Requirements".

A. IMPROVEMENT IN MAJOR AIRPORT PERFORMANCE

Figure 14 shows the new volumetric capability provided by MLS via a greatly increased azimuth coverage (±60 degrees for MLS vs ±3 degrees for ILS) and elevation coverage (1 degree to 20 degrees for MLS vs ±0.7 degree for ILS). At major air carrier airports, this extended coverage will provide the capability for making curved and segmented approaches, thereby permitting traffic to be routed away from populated areas in favor of waterways, parks, and other unpopulated areas, with the desired result of reducing population noise exposure. In some cases it will be possible to increase instrument-flight-rule (IFR) capacity and improve air-traffic-control (ATC) efficiency. Flight paths can be shortened for those properly equipped aircraft that currently must fly away from the airport in order to intercept the narrowly defined extended-centerline ILS approach course. In regions with major airports in close proximity, restricting aircraft to extended-centerline paths may result in intersecting arrival paths and a consequent slowing of operations at both airports. The usefulness of curved approaches to resolve these types of airspace requirements is well recognized and currently employed at some airports when the weather is good and pilots can navigate by visual reference. Precision guidance with MLS would permit these approaches to be coninued to be made under IFR weather conditions or at those locations where visual references are inadequate.

The sensitivities of ILS to terrain features have been accommodated at most large airports by expending the funds necessary to grade and fill sites. However, in a number of instances an ILS could not be economically installed, or installed only with minimums that do not meet Category I. In addition, in some instances, ILS sensitivities have required restrictions to be placed on airport surface traffic with a resultant decrease in IFR airport capacity.

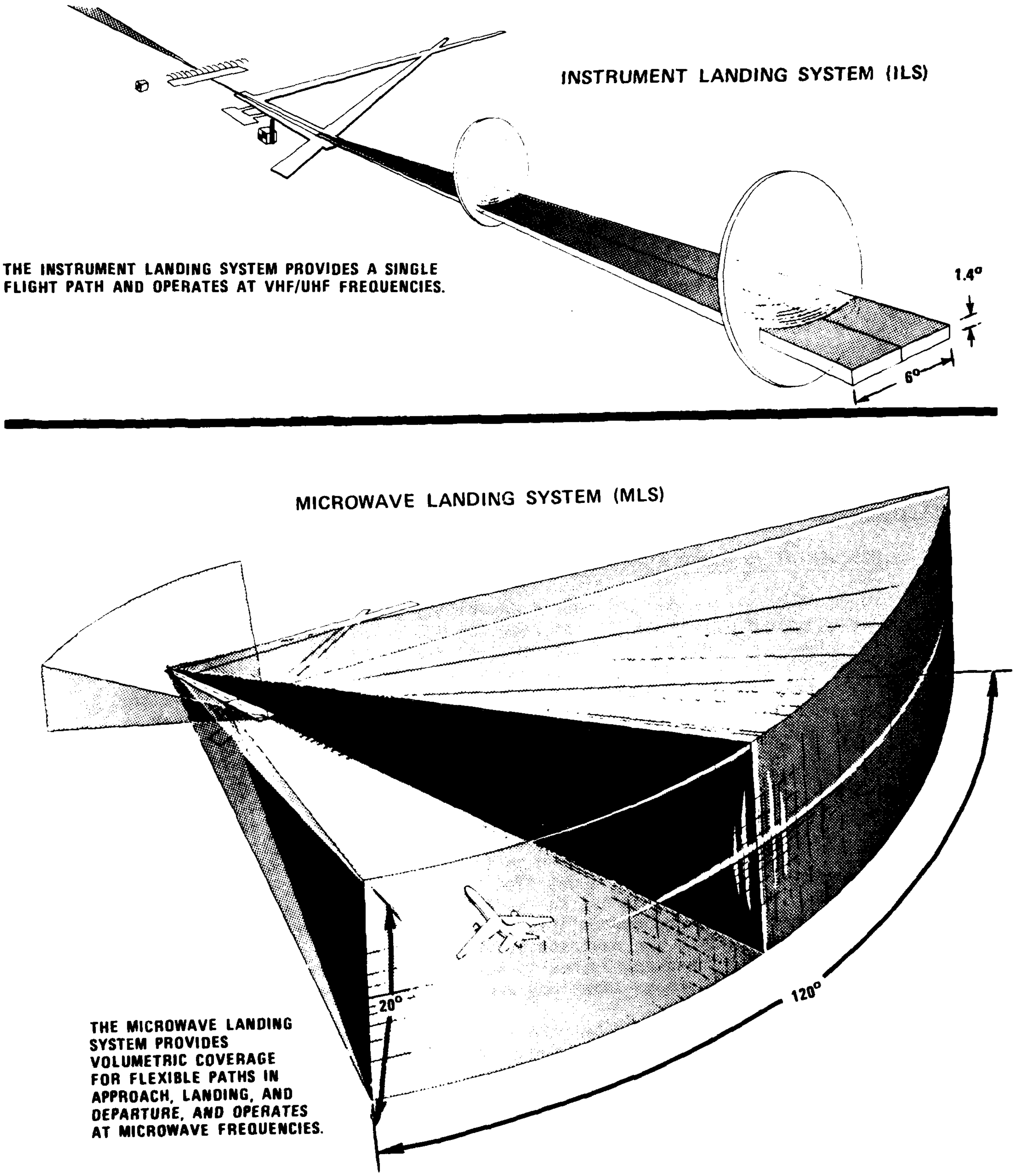


Figure 14. Description of Instrument Landing System (ILS) and Microwave Landing System (MLS).

To illustrate and quantify the application of MLS benefits discussed above, a case study of five major air carrier airports was conducted. A summary of these requirements analyses is presented below.

1. More Effective Airspace Use. The application of MLS to support more efficient airspace use has shown that the approach and missed-approach airspace for certain runway configurations at New York's Kennedy (JFK) and LaGuardia (LGA) airports can be separated using MLS curved approaches. The ILS approach paths in figure 15 illustrate two representative conflicting airspace problems between LaGuardia and Kennedy airports. The two airspace conflicts are: (a) arrivals to LGA runway 13 and JFK 13; and (b) missed approach at JFK 4 and arrivals to LGA 31. The decoupling of these IFR operations can increase the average runway capacity at LGA by about 3 percent. With MLS, the associated annual delay at LGA could be reduced by as much as 100,000 minutes for current operations and by as much as 150,000 minutes for operations forecast in the year 2000. These delay estimates were derived by assuming current traffic profiles, IFR conditions, and that the preferred MLS runway configuration would be in use.

2. Noise Reduction. Currently, there are eight VFR approaches used for noise reduction at the five case-study airports. When modified to meet MLS requirements, these approaches expose from 16,000 to 192,000 fewer people to 75-dB(A) noise levels than the current IFR approaches to those runways. At 85 dB(A), there is no discrimination between the current IFR approaches and the MLS approaches except at JFK, which indicates that a substantial noise benefit is possible during an MLS approach to runways 13L and 13R. The use of these runway approaches exposes between 13,000 and 23,000 fewer people to 85-dB(A) noise levels. MLS can support five of the eight VFR approaches in their present form; one would have to be modified to have a 2-nmi extended-centerline. The use of another approach would depend on changes in future obstacle/TERPS criteria, and the eighth would depend on extended-centerline and airspace modifications. Since there was no attempt to optimize the approach paths for noise, MLS may support more noise-effective IFR and VFR approaches than the VFR noise approaches at some locations because the VFR approaches are generally restricted to using visual landmarks and, thus, may also be constrained to noisy low-altitude profiles that would not be required with MLS.

Noise departures during IFR weather can be reduced at San Francisco (SFO) airport by providing MLS departure guidance from runway 28L. With MLS, the number of people exposed to an 85-dB(A) noise level is reduced by an average of 2,000; at 75-db(A), approximately 14,000 fewer people are exposed per departure.

3. Reduced Approach Minimums. IFR approach minimums could be reduced at Washington National (DCA) airport using MLS guidance. This would improve an IFR capacity-restricting situation that occasionally occurs when weather conditions require landings from the north and takeoffs to the south on the single north-south runway, 18/36. A variety of approaches to accomplish this objective have been devised, as shown in figure 16. The extent of the capacity improvement would depend on future IFR curved-approach minimums associated with short extended-centerline finals and near-in obstacles, and the frequency of occurrence of IFR conditions and their effect on these minimums. If full, unrestricted, Category-I minimums could be supported, then annual delays might be reduced by as much as 65,000 minutes. These estimates are based on the assumptions that existing traffic profiles and IFR conditions prevail throughout the day.

JFK/LGA

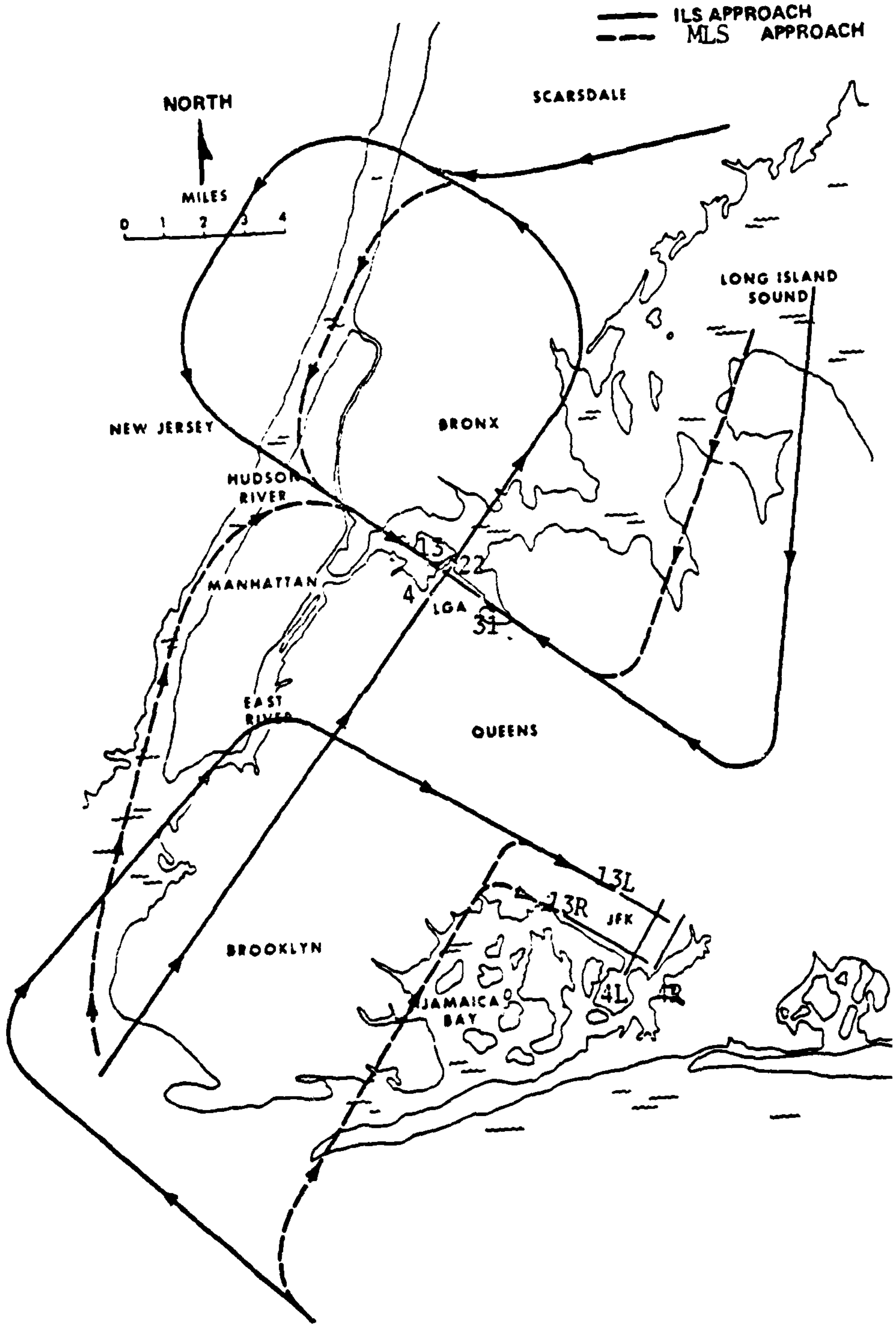


Figure 15. Example of Efficient Airspace Use with MLS.

DCA RUNWAY 18 OPERATIONS

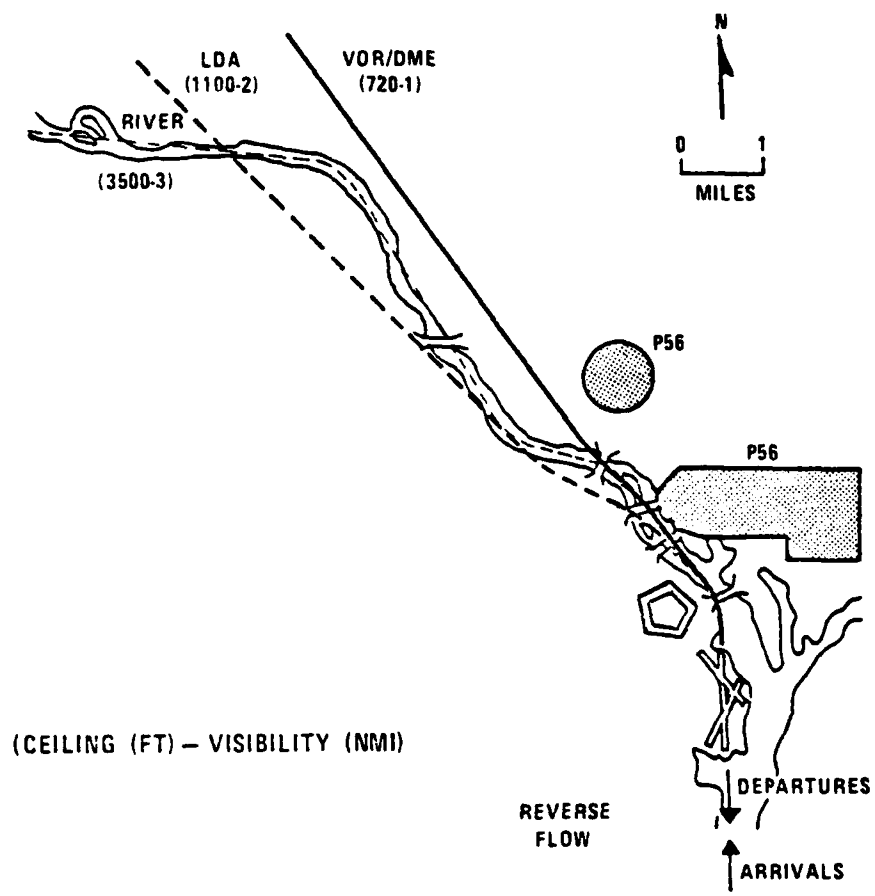


Figure 16. Example of Reduced Minimums with MLS Precision Guidance.

4. Reduced Delays from Taxiway Restrictions. The problems caused by taxiway flow restrictions for departing aircraft near the critical areas (signal interference area) of the ILS glideslope antenna, can be resolved by MLS at all sites investigated. An example of this restriction problem is shown in figure 17. The glide-slope antennas for both runways 4L and 4R at JFK are located on the taxiway side because Jamaica Bay precludes the use of a ground plane for forming a proper beam on the other side of the runway. Assuming IFR conditions and no runway configuration changes, the installation of MLS on JFK runway 4L/R would lead to higher IFR airport capacity and greater operational flexibility. If all operations were IFR, the reduction in delays could be as much as 140,000 minutes annually based on present operations, and by 1.5 million minutes in the year 2000. For the period from 1985 to 2000, the savings would amount to 293.50 million gallons of fuel. This glide-slope location

JFK RUNWAY 4 L/R OPERATIONS

● ASSUMPTION

INDEPENDENT SIMULTANEOUS IFR ARRIVALS TO 4 L/R

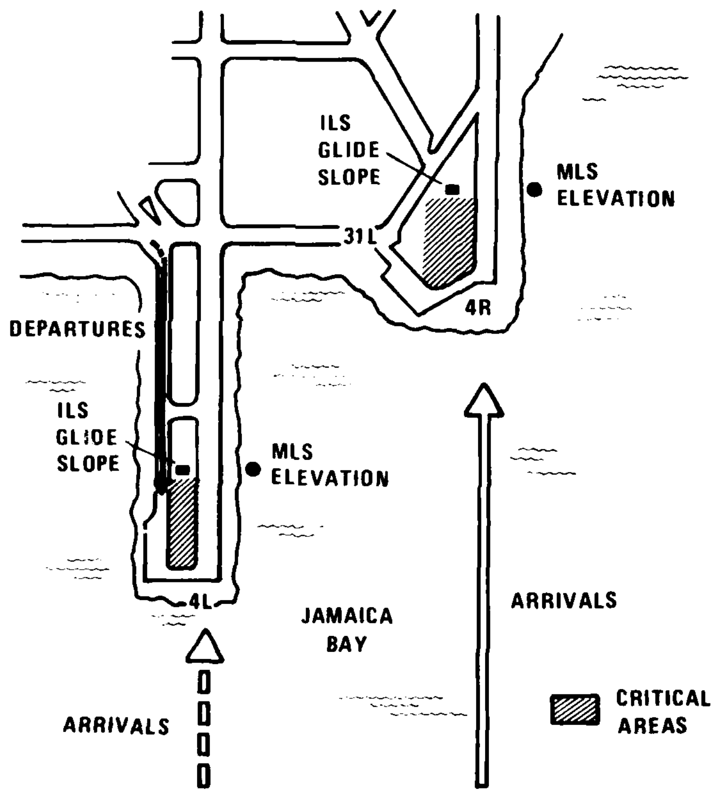


Figure 17. Example of Removal of Ground Traffic Restrictions with MLS.

problem could be resolved with ILS only by using expensive cost measures such as extensive landfills or other site modifications. However, environmental constraints (e.g., a bird sanctuary) may negate this alternative. At Seattle (SEA) airport a similar glide-slope signal interference problem might be resolved, for example, by moving the ILS glide-slope antenna on 34R at a cost of $350,000 to $500,000 for the needed land fill and the embedding of approach lights.

5. Other Performance Requirements. Other potential problems involving Category-III operations at some locations could be minimized with MLS. These include provisions for flare guidance at Seattle and rollout guidance at San Francisco where operations with the currently configured ILS installations would be difficult. Additionally, an advantage in maintenance scheduling and availability of the landing system could be provided by MLS at three of the five case-study airports (JFK, LGA, SEA). Finally, because of the large number of available channels, MLS would remove the current ILS-channel operational constraint.

Based on an MLS requirements survey of the Airport Operator's Council International, it was determined that 72 percent of the 59 large- and medium-sized hub airports surveyed perceive a need for MLS to resolve the types of problems encountered at the case-study airports.

B. RELIEF OF ILS CHANNEL LIMITATIONS

ILS currently has 20 frequency channels available, and the number of ILS installations in the U.S. is approximately 600. For some portions of the country, the 20 ILS channels are already inadequate to supply the precision guidance service which is needed. Figure 18 depicts the areas in the U.S. where channel limitations existed in 1971. The situation is much more acute today.

An expansion of ILS capability to 40 channels is possible by channel splitting to 50-kHz separations. However, even with 40 channels many locations needing service may not be able to have an ILS beyond the 1400 system level because of siting and signal obstruction problems. It is also important to note that channel splitting would require aircraft to have 50-kHz receivers rather than the present 100-kHz sets. This would impose a severe economic burden on those aircraft that are not currently equipped with 50-kHz receivers, requiring an expenditure of almost $200 million for avionics conversion costs. This conversion would have to be made sometime before the channel congestion problem became severe; estimated to occur at the 930th ground installation, approximately. As currently forecast, this installation is scheduled to take place in the year 1988. If all aircraft owners waited until this year to make the avionics conversion, the discounted value of the $200 millions spent in the year 1988 (discounted at an annual rate of 0.10) would be the $90 millions shown in table 5. The conversion might also present a serious operational problem during the conversion period since there would be a combination of 50-kHz and 100-kHz equipment on the ground and in the air.

The detailed breakdown of conversion costs by user group is shown in table 11.

In summary, the lack of adequate channels is a barrier to future growth potential. Precision approach and landing service may be denied to users who will require this service in the future. MLS has 200 channels available--adequate for any foreseeable future need.

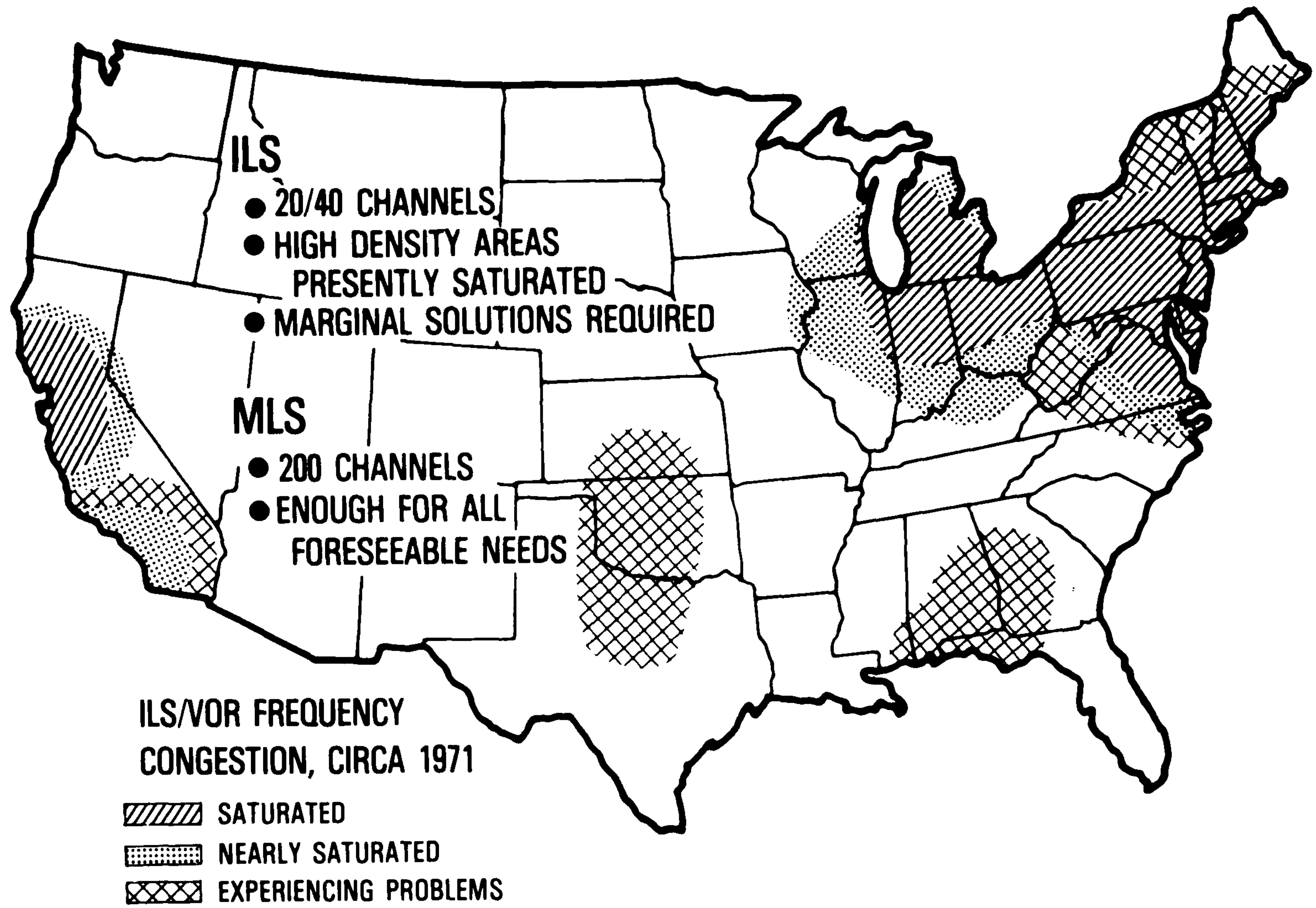


Figure 18. ILS Channel Limitations and MLS Relief.

Table 11. TOTAL FLEET COSTS TO CONVERT ILS AVIONICS TO 50 kHz
(In millions of 1976 dollars)

User Group	National Requirement (1250 Ground Systems)	
	Quantity of Aircraft	Cost* (millions)
Air Carrier	3,629	$ 18.1
Commuter Airline	1,370	5.5
General Aviation:		
Corporate Jet	7,280	29.1
Private Propeller	226,600	141.2
Totals	238,879	$193.9

* Costs are in millions of actual year, undiscounted, dollars.

C. FEDERAL COST REDUCTIONS

Ground system costs for the MLS are expected to provide considerable savings to the government compared with the corresponding costs for ILS. The ILS has a history of relatively high costs at some locations due to glide-slope site preparation problems. Maintenance and flight inspection costs have been somewhat high because of tube-type equipment and inherent ILS signal instability. However the maintenance problem is being improved with solid-state ILS installations. See table 6, (p. 32) for cost comparisons of unit ground installations.

1. Cost Savings. Major cost savings accrue to the government when the small-community MLS (SCMLS) is installed instead of an ILS. The SCMLS provides Category-I guidance, and is less expensive than the basic MLS. It does not have a DME transmitter, and permits only a straight-in approach, as does ILS. However, it does have a wider area of proportional coverage (±10 degrees versus ±2 degrees for ILS). This version of MLS provides greater capability than the Category-I ILS. Average savings in initial costs are $88,800 ($312,900 minus $214,100) or about $100,000 for each of these systems installed at a new Category-I site. The total reductions in 20 year program costs for all service levels and airport types are shown in section III, Economic Analysis, of this volume.

2. Operating and Maintenance Costs. The historically high maintenance costs of the ILS result from two factors inherent in the design. They are the tube-type nature of the majority of ILS used and the extreme sensitivity of the transmitted signals to small changes in the environment surrounding the ILS. The problems with tube-type equipment are being improved through the installations of solid-state ILS. However, the oversensitivity of ILS to environmental changes results primarily from the VHF/UHF frequencies utilized by ILS. These difficulties can only be partially alleviated, even by complete system redesign, including new antennas. This innate instability has an effect on the number of flight inspections required to maintain system service.

Periodic flight inspections and maintenance adjustments ensure that the precision landing aids continue to meet the standards required for safe operations. The FAA performs periodic flight inspections at both civil and military airports. The ILS also has electronic monitors located near the localizer and glide-slope transmitters to detect disturbances or deteriorations of the transmitted signals. If the signal-in-space exceeds the present tolerance limits, the monitors cause the operating transmitter to be shut down and signal the cognizant FAA facility. For Categories II and III, the ILS monitor automatically causes the standby transmitter to become operational. However, experience has shown that the ILS does not always provide accurate information to the user even when the electronic monitors do not detect an out-of-tolerance condition in the radiated signal. The signal change may be due to site changes or interference caused by man-made obstructions located beyond the monitor point. Flight inspections are, therefore, necessary to augment the monitoring capability.

Potential savings in flight inspection costs should result with MLS because of a reduction in discrepancies presently not detected by ILS ground monitors and test equipment, and because of a reduction in the number of periodic checks required annually. The ability of MLS to detect out-of-tolerance conditions with its ground monitor equipment, and diagnose needed maintenance corrections for such conditions without flight-inspection verification, provides the potential for virtually eliminating nonperiodic inspections. However, the elimination of nonperiodic inspections could only be achieved after considerable operational experience with MLS. The stability of the MLS system, its relative freedom from external influences, and its elimination of the modulation functions all contribute to the potential for extending the interval between periodic flight inspections. Extending this interval from 4 to 8 months for MLS would reduce the cost of periodic inspections from approximately $7,250 to $3,600 per facility per year. These savings estimates are supported by recent test results. The MLS development program has completed feasibility and prototype system development, and test results are producing evidence to support the expected performance stability.

D. MLS FOR THE UPGRADED THIRD ATC SYSTEM

In the 1960's, delays encountered by scheduled airlines became so severe that the DOT Air Traffic Control Advisory Committee (ATCAC) concluded that air traffic was in a crisis due to the failure of airports and ATC capacity to keep pace with the growth of aviation activity. The 1969 ATCAC report concluded that the Third Generation ATC System would not be adequate to meet the demand for ATC service beyond the late 1970's. To meet this increasing demand, ATCAC recommended that the Third Generation ATC System be upgraded. This recommendation was approved by the Secretary of Transportation, and in 1970 development began on the nine features of the "Upgraded Third Generation ATC System" (UG3RD). The basic features of the UG3RD include:

- Discrete Address Beacon System (DABS)
- Upgraded Automation
- Wake Vortex Avoidance Systems (WVAS)
- Area Navigation (RNAV)
- Microwave Landing System (MLS)
- Intermittent Positive Control (IPC)
- Airport Surface Traffic Control (ASTC)
- Flight Service Stations (FSS)
- Aeronautical Satellite System (AEROSAT)

The major ATC requirement for the future is to accommodate the anticipated growth in aviation activity. This goal is incorporated into those UG3RD programs designed to increase capacity and controller productivity. The greatest increase in capacity will result from a decrease in required aircraft separations afforded by the Wake Vortex Avoidance System. However, additionally required increases in capacity and controller productivity will come as a result of Upgraded Automation in conjunction with more accurate surveillance and navigation.

The increased capacity and controller productivity of the UG3RD requires some form of area navigation to safely achieve the projected performance improvements. Although VOR/DME RNAV can meet the navigation self-delivery requirement for enhanced controller productivity, MLS RNAV accuracy is necessary for the safety requirements of the future UG3RD ATC in the event of a ground surveillance or communications system failure. In addition, growing environmental restrictions on terminal-area path deviations may lead to a requirement for fixed-path approaches to reduce community exposure to aircraft noise. To implement a fixed-path type of approach control as well as for safety and controller productivity, the accuracy of MLS is required as an integral part of the UG3RD to achieve the projected ATC performance improvements.

E. SERVICE TO SMALL-COMMUNITY AIRPORTS (GENERAL AVIATION AND COMMUTER AIRLINES)

Benefits are expected to accrue to not only major airport users but also to non-air carrier users of small community airports. These users include CAB certificated scheduled commuter airlines, air taxi operators, business jet operators, private plane owners, and others who fly for business, pleasure, and training.

Today, the small-community airports used by commuters and general aviation have fewer ILS facilities, less funds and more accidents than the major airports. Precision guidance service installed at these airports will provide an added measure of safety for all landings regardless of the weather, but only a portion of these benefits which could be quantified for IFR operations when combined with IMC conditions, were included in the Economic Analysis shown in section III.

1. General-Aviation Benefits. The general-aviation and commuter airline segment of the aviation user community is the largest and fastest growing user group, with about 50,000 aircraft currently ILS equipped, and growing to an estimated 120,000 by 2000 A.D. The principal benefits of MLS to general aviation and commuter users arise from the availability of precision approach and landing guidance service at locations that otherwise could not be provided with ILS service either because they do not qualify under the present Airport Planning Standard (APS-1) or because of ILS problems of siting, installation, and channel limitations. MLS has the potential for more widespread implementation because of lower costs, simpler siting requirements, and better signal quality than ILS.

2. Small Airport Safety Improvements. Small airports have not been able to apply the same level of financial resources to overcome ILS siting problems as have the larger airports. As a result, a number of airports either have installed full ILS systems with performance reduced to below Category I via non-standard locations, or they have completely foregone a full ILS installation. A number of other airports have not installed ILS because of site preparation costs. Still others do not qualify under APS-1. The absence of vertical guidance has historically resulted in a lower level of safety associated with landing operations (see Volume I, Chapter 1 for a detailed discussion of safety benefits).

A study was conducted of the potential MLS contribution to a reduction in landing accidents. Based on the 1964 to 1972 National Transportation Safety Board (NTSB) history of landing accidents, precision-landing-equipped airports have had far fewer instrument-weather landing accidents per million instrument approaches than have nonprecision-equipped airports. The presence of a precision landing aid at an airport was estimated to reduce the probability of a landing accident by a factor of 2.5 for general aviation and a factor of 8 for air carriers. The economic analysis shown in section III calculated that the wider deployment of precision guidance with MLS will result in a reduction in instrument-weather landing accidents. However, additional and subsequent analyses by the NTSB and by the CAA in Great Britain indicate that the use of precision guidance in VFR weather contributes significantly to improved safety. The magnitude of this improvement may even be equal to that provided during IMC weather.

3. Interim Standard MLS. An Interim Standard Microwave Landing System (ISMLS) has been approved for limited use in locations where installation of the current VHF/UHF ILS is not practicable. On August 20, 1974, the FAA selected the system developed by Tull Aviation Corporation, Armonk, New York, as the ISMLS prototype. In selecting this system it was clearly stated that:

> "the FAA intends the ISMLS for limited application and use at locations where a VHF/UHF ILS will not perform in an effective manner or where the needs for a low-approach service would be better met by the use of the Interim Standard System" and "that limited application of the ISMLS will not detract from the National MLS Program."[5]

Subsequent actions included preparation and issuance of revised Federal Air Regulations (FAR, Part 171), which specified the approved signal format and technical requirements that must be met for the ISMLS to be installed and used in public service as a non-Federal aid. Additionally, the APS-1 for terminal navigation facilities was revised to include the establishment criteria for ISMLS. APS-1 re-emphasizes the criteria state in the Notice of System Selection; namely, that:

- Installation of ILS must be technically infeasible;
- The airport is remotely located and a cost/benefit study shows ISMLS to be more cost-effective; and
- Establishment of ISMLS will be discontinued upon availability of standard MLS.

[5] "ISMLS Notice of System Selections," dated August 23, 1974.

FAA policy relative to ISMLS and its intended role vis-a-vis ILS and MLS was recently restated by the Administrator in a letter dated April 6, 1976. The subject of the policy statement was "Agencywide Policy Relating to the Microwave Landing System Program." This letter made it clear that, pending the availability of MLS, the ILS is the preferred system. ISMLS deployment will be limited to those locations where a VHF/UHF ILS will not perform effectively or where the user's needs would be better met by the use of an ISMLS. If a decision is made to begin national implementation of MLS, the users of ISMLS will incur an additional cost (not estimated at this time) to convert their avionics so that they are compatible with the national MLS signal format.

4. The Small-Community MLS. The needs of the general aviation segment of the user community were recognized early in the MLS program, resulting in the development of the small community MLS (SCMLS). The SCMLS more than meets all the requirements of general aviation users concerned principally with Category-I straight-in approaches. The SCMLS exceeds performance of the ILS, is fully compatible with more sophisticated versions of MLS, will provide for civil/military interoperability, and meets all International Civil Aviation Organization (ICAO) Operational Requirements. SCMLS prototype hardware, both ground and avionics, has been built and is currently undergoing test and evaluation by FAA, NASA, and DOD.

Based on current installation criteria for ILS, APS-1, an estimated 1250 precision approach and landing systems will be in place by the year 2000. The emphasis on turbojet operations and annual instrument approaches favors the installation of ILS at airports which serve the air carriers. The APS-1 criteria are, therefore, not responsive to the needs of the general aviation user operating out of the smaller airports.

APS-1 attempts to establish criteria based on economic factors, including the cost of implementing and maintaining a system. Hence, more systems will qualify for implementation if they are less expensive to install and maintain. The SCMLS ground system, manufactured and installed to FAA specifications, is estimated to cost $214,000 complete. ILS ground installations have typically been running an average of $312,000, or about 50 percent higher. Therefore, if the SCMLS is installed in place of ILS, an increase in service is possible at the same overall cost to FAA.

An estimate of the increase in precision guidance service, represented by the additional number of SCMLS installations that would qualify under the existing ILS Installation Criteria APS-1, can be obtained by noting that 600 newly qualified ILS installations are forecast to be made at small community airports by the year 2,000. An additional 300 systems, to a total of 900, would, therefore, qualify for SCMLS installations for the same FAA investment costs. When the effects of life-cycle costs are inputed into the dollar calculations required by APS-1, the operating and maintenance cost advantage for the SCMLS ($18,000 annually vs. $27,000 for the ILS; ref. table 6) would result in additional small airport locations qualifying for SCMLS service.

F. FUTURE AIRCRAFT TECHNOLOGY

The use of MLS is especially beneficial to future short-haul aircraft (V/STOL, RTOL, etc.). These benefits are obtained through MLS guidance coverage and accuracy, which enable the effective all-weather use of steep

departure, steep approach, small turning radius, low maneuvering speed, and short runway takeoff and landing capabilities characteristic of these aircraft. Specific benefits are: (1) improved noise abatement, (2) improved obstacle clearance safety margins, (3) more effective use of available airspace, (4) minimized time in enroute operation, (5) utilization of airports with difficult terrain features, (6) improvements in air transportation service to small communities, (7) relief of congested high-density terminal areas through improved utilization of secondary airports, and (8) improvements in high-density airport operational capacities. These benefits are critically important to the effectiveness and viability of short-haul aircraft by permitting this type of aircraft to operate as designed.

ILS cannot provide the kind of precision guidance needed for future V/STOL and RTOL aircraft. Therefore, MLS is necessary to fully exploit the potential of these future aircraft.

G. MILITARY REQUIREMENTS

During and since World War II, the military services have used two main precision approach and landing systems, ILS and ground-controlled approach (GCA). These systems have proved invaluable and have met the requirements of the military except for certain specific operations such as aboard aircraft carriers and in forward areas.

Each of these two systems has some drawback for one or more of the military services. GCA in conjunction with precision approach radar (PAR) offers universal interoperability (only a radio receiver is needed in the aircraft), but lacks mobility, flexibility of operations, and performance in heavy rain. GCA also is costly to operate in terms of parts replacement and manpower. The ILS meets the Air Force needs to a large extent and is compatible with national and international operations. It has no value to the Navy for use aboard ship nor to the Army and Marine Corps for use in forward areas. ILS lacks ease of installation in many areas and requires real estate that is not always available nor protected in battle zones.

Because of these ILS and GCA deficiencies, the military services embarked on a research and development program in the 1950's to obtain suitable precision approach and landing systems to meet their needs. The Navy now has a landing system aboard aircraft carriers that combines both GCA and ILS features into the fully automatic Aircraft Landing Control System (ALCS). The Marine Corps has a similar system under procurement for tactical use. The Navy and Marine Corps' new microwave landing systems use the same avionics and are, therefore, compatible. The Marine Corps system is designed to meet forward-area requirements of mobility and quick setup time.

The Air Force developed and is procuring a highly sophisticated GCA for tactical purposes that overcomes many of the GCA deficiencies previously stated. The Air Force is also providing conventional ILS capability at more air stations and to an increasing number of aircraft:

Although the military services have vested interests in different types of precision guidance systems, they are all committed to the National MLS Development Program.

1. Military Commitment. The Department of Defense is committed to joint development and test of the National MLS. Based upon an MLS capable of fulfilling military tactical requirements, the military services are expected to achieve the following benefits:

- A material reduction in the number of GCA units, with the attendant reduction in personnel and maintenance costs.

- Operational flexibility and mobility to satisfy military tactical requirements.

- Civil/military commonality to improve operational capability and reduce research, development, procurement, training, and logistics costs.

2. Present Procurement Plans. The present plans of the three U.S. Military Services to place MLS into operational use are briefly summarized in the following paragraphs.

a. U.S. Army. The Army stated a definite requirement for 15 tactical MLS ground systems as early as FY 1979. A total of 106 MLS would be procured by FY 1984. MLS avionics would be procured starting with 500 in FY 1980, and totalling to 7,675 by FY 1986.

b. U.S. Air Force. The USAF plans to procure 20 tactical systems, 250 fix-based systems, and avionics for about 8,500 aircraft. This implementation could begin as early as the mid-1980's and extend for 10 to 15 years.

C. U.S. Navy. The U.S. Navy plans to equip 13 aircraft carriers and 55 Navy and Marine Corps shore-station airfields with MLS. An additional 45 remote-area systems and 17 expeditionary systems would be required for tactical purposes, not including spares. The planned inventory of 5,600 Navy and Marine Corps aircraft would also be equipped for use with MLS. Aircraft procured in FY 1983 and subsequent years would be procured with MLS. Aircraft in the inventory in FY 1983 with at least 10 years of projected operational life remaining would be retrofitted with MLS.

The shore-station systems would be procured at the rate of 10 per year between FY 1981 and FY 1989. The 13 aircraft-carrier systems would be procured commencing in FY 1982 at the rate of 2 or 3 a year. Approximately 6,000 aircraft systems would be procured in FY 1981 through 1989. The tactical ground systems would be procured between FY 1983 and FY 1989.

The benefits to the Navy are heavily dependent upon timing. Any further delay in the availability of MLS would necessitate the continued reliance and investment in present systems and their development. Should shipboard system performance of MLS not be demonstrated prior to 1980, the Navy would then need to pursue development of a new system to replace ACLS aboard ship, as well as PAR on shore.

3. Military Benefits Summary. In order to achieve the benefits of an internationally standardized system for both civil and military use, the U.S. Military Services are committed to joint development and implementation of MLS. Given that MLS is approved by ICAO and is capable of fulfilling the military tactical requirements, it is concluded that the annual costs to the military

services of landing systems could be significantly reduced by replacing existing military landing systems with MLS.

In a recent study (complete study is in Volume II), it was concluded that, by replacing existing military landing systems with MLS, the annual cost of Operation and Maintenance (O&M) to the military services would be reduced. The date at which this reduction would be realized is dependent upon the implementation plan or scenario used. The annual O&M costs could be reduced from the current annual rate of $102 million to a rate of $65 million upon completion of implementation. Much of this $37 million cost reduction stems from a reduction of operator and maintenance personnel from 3,388 to 1,621.

One of the principal MLS benefits to the military will be the national and international flexibility at all civil and military fields provided by MLS as a worldwide standard. This commonality will not only improve operational capability, but will also reduce research, development, procurement, training, logistics, and operating costs.

H. INTERNATIONAL MLS MARKET

When MLS (either TSRB or Doppler) is adopted as a worldwide standard, a potential international market for U.S. manufactured equipments will develop. Historically, U.S. manufacturers of civil aviation products have held a strong position in the world market (approximately 70 percent). However, most governments now recognize the value of civil aviation activity, both manufacturing and operating, as an instrument of national and regional policy. Accordingly, they are providing direct financial and political support to developments that benefit their civil aviation activities. The impact of their participation in the manufacturing, marketing, financial, and political aspects of the industry is increasing. Nevertheless, despite the international penetration, the total MLS sales anticipated for U.S. industry during the next 25 years is just less than half of the projected $2-billion total MLS market, approximately $900 million.

I. OPINIONS AND REQUIREMENTS EXPRESSED BY USER ORGANIZATIONS ABOUT MLS

As part of the analysis of requirements for MLS, a review was made of the opinions of the following user organizations:

- Air Transport Association (ATA)
- Airport Operator's Council International (AOCI)
- Aircraft Owners and Pilots Association (AOPA)
- Commuter Airline Association (CAA)
- Experimental Aircraft Association (EAA)
- General Aviation Manufacturers Association (GAMA)
- National Business Aircraft Association (NBAA)
- National Pilots Association (NPA)
- U.S. Military

Extracts of correspondence and statements by these organizations are contained in Volume I, Chapter 2, section 2.11.

☆ U.S. GOVERNMENT PRINTING OFFICE 1980 721-270/155

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